EVERYMAN'S GEOLOGY

OF

THE THREE PRAIRIE PROVINCES

OF

THE CANADIAN WEST

BY

GEORGE BRYCE, LL.D., F.R.S.C.

Lecturer in Geology (1891-1904) in the University of Manitoba
Winnipeg.

MAPS AND DIAGRAMS

WINNIPEG

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PREFACE.

Frequent requests are being made by settlers, home-seekers, explorers, prospectors, travellers, teachers, scientists, and others, for information as to the physical and economic conditions of the great prairie provinces of the Canadian West. There is no work now in existence to meet this demand. The underlying and neighboring rocks give their character to the soil; the layering of the drift can only be understood by the account of its deposition, and the glacial conditions which it has undergone. The vast system of inland lakes which formerly existed must be studied to explain present conditions. The vital questions of water supply, artesian wells, mineral character of the water, alkali, soils, etc., depend on a knowledge of the geology of the country. Money, time, and trouble may be saved in the search for salt, gypsum, lime, cement, building material, coal, petroleum, and other minerals by acquaintance with the local features of the country.

It is hoped that this short sketch may to some extent supply the need spoken of.

It is suggested that teachers in schools should make collections of specimens of the rocks, minerals and ores mentioned in this work for the information of their pupils.

A short Appendix is added showing the connection of forestry with the soil features, humidity, and general climatic conditions of the prairies.

INTRODUCTION.

A.

A TRAVELLER'S VIEW.

An observing Canadian farmer had made up his mind to visit the Canadian West. He was a man of fifty and was born near London, Ontario. Brought up to the farmer's life, he had been diligent and had accumulated a fair competence. His paternal abode had been a farm of one hundred acres—a fair example of the agricultural homes of Ontario, in which province there is as equal a distribution of wealth, as high an average of intelligence and as great a degree of comfort without luxury, as is found in any part of the world.

But the farmer's sons—a stalwart crew—were growing up and the ancestral home was too strait. By usage of primogeniture the eldest son might live upon the farm, with its well appointed stone dwelling, its barns and stables, and its horses, cattle and sheep, but it could not well be divided. To the West! was the only resource, and the father started out on a tour of exploration.

As the traveller in August went upon his way to take the Winnipeg train from Toronto, he passed the Woodstock and Brantford region with its hills and dales, and it looked more beautiful than he had ever seen it before, for he was leaving it behind. The Grand Trunk Railway from Toronto took him northward and the peaceful stretch of Lake Simcoe lay more placid than ever, but the traveller was soon to pass into a new and to him inexplicable region.

Like all men who have lived laborious lives, our farmer was in some things narrow and prejudiced. His idea of a farm was one of a hundred acres; it must be well-lying, arable land and it must be so many miles from town—just the distance his father's and his own had been. Nothing else for him. His notion of farming was also rather traditional. Being somewhat of a reader he took of course the agricultural journals, but put little store on them. The Agricultural College was all very well in its way, but his sons did not need it any more than he had done. He was a level-headed man, and his horror was "fads" in farming, education or religion.

Soon the Muskoka region was reached, and its beautiful lakes, over which New York tourists go into raptures, "but how," said the farmer to himself, "do the people make a living ?" "Rocks! Rocks! Rocks!—and more rocks. This is alarming."

True, he had once before seen something like it. He had taken a summer tour down the St. Lawrence River, and had seen the Thousand Islands, with their hard, gray or whitish rocks, but they could not be farmed. He had on the same journey gone from Montreal to New York by the Adirondack route, and had passed its cliffs covered chiefly with pines and spruces, and in its valleys had seen the great boulders lying along the streams and hillsides. Even his unpractised eye saw that these were the same rocks as those of the Thousand Isles, and here they were in Muskoka. "Every man," he declared, "must admit that here there is no living for any one."

He had observed another thing, however, viz : that the stones from which he had built his own house on the home farm, familiarly called "hardheads" or "field stones," and which he had gathered from a leading ridge which ran through his farm, seemed to be in composition the same as the Muskoka, Thousand Islands and Adirondack rocks; but how in the world did they reach the London district with its fertile stretches of land ?

One of his neighbors, Farmer Brown, who was a bitter opponent of the "new larnin'," maintained that these "boulders," and some of them were half a ton in weight, grew where they lay. "Everybody," said Farmer Brown, "knows that stones grow. I don't know that it is in the Bible, but I know that the statement is centuries old, and I hold," he continued, "that these boulders grew right here on your farm. This modern nonsense about ice and water heaping up these piles of stones sickens me."

Our farmer did not believe much in the Brown philosophy, and was getting more light in his travels.

In the course of time the Western traveller reached North Bay and was really distressed as he thought upon some parts of this unprofitable region extending for a hundred miles along the line upon which he had travelled.

It was late in the evening when the westbound investigator joined the Canadian Pacific Railway North Bay, now to make without change his run of more than a thousand miles to Winnipeg. Soon after leaving North Bay he saw in the moonlight from his car the broad expanse of Lake Nipissing, which he was soon to leave behind.

He observed in the time table that he was to pass Sudbury, which he knew had a "nickel" reputation, but it was not for him. Before morning he found that he had been wheeled along more than three hundred miles to the west, where he heard at Missanabie that the streams ran northward to James Bay—the southern

part of Hudson Bay—and that south in less than thirty miles the southern flow took place into Lake Superior.

But oh! what a forenoon it was from Missanabie to Heron Bay, where the Canadian Pacific Railway touches Lake Superior! Round topped hills of solid rock, with streamlets running down the valleys, and the constant succession of the hills rose covered with white spruce trees, varied with a few pines or now and then a poplar or silver birch. His old acquaintances, the rocks of the Thousand Islands and the Adirondacks, were still here. The interminable stretches had boulders in heaps here and there, some flats were in view with their sand beds, or here and there was a stretch of clay. These were evidently the work of the water, freezing in winter, splitting the rocks in spring, tearing the cliffs asunder, breaking up the rocks into stones, rolling them over and forcing them into ridges. All was plain to the farmer now and he quietly remarked, "I see that Farmer Brown was wrong in his statements."

This was a forenoon experience, but what of the afternoon from Heron Bay to Fort William? It was exciting in the extreme. This sight of the gigantic lake front greatly affected the traveller. He seemed to be sweeping around the cliffs many feet above the lake, and along a rocky shelf hollowed out by man on which the railway passed. He looked down with wonder into the depths of the cold, blue lake. What a coast! Inhospitable, barren, rocky. For what was it made? It was this terrible barrier that stood in the way of Canada, for many years, connecting itself with the West, and it was only Canadian pluck and Canadian engineering that blasted a road through the rocks and made Eastern and Western Canada one.

"What can be the use of these rock regions," soliloquized the farmer. "I see no purpose—leaving out the mineral wealth which may be buried here, of which I know nothing—unless this is the storehouse from which ground down to powder by ice and water all the soil which makes up our fertile fields has been formed. But none of it for me; let me go back to my Ontario acres." Fortunately the traveller had his ticket to the fertile prairies of the Western provinces—the land of Canada's hope.

He was pleased, however, by the beautiful river Nipigon, and he was informed that this flows from a great lake of the same name.

Toward evening appeared the great Inini-Wudgoo height, with its rounded cliffs along the lake, and prominent shooting into the sky the great promontory of Thunder Cape, while at its foot lay the wide stretch of Thunder Bay. Their grandeur impressed the heart of the farmer, but his utilitarian spirit had a hard struggle with the artistic.

Kindly night dropped her mantle over three hundred miles of the same round-topped hills, with their falls and rills, till early morning brought the train to Kenora, (Rat Portage), where the curtain-fall from Lake of the Woods drops down into the headwaters of the Winnipeg River, a clear stream, which however, takes its name from the lake of the same name—the "lake of murky water."

Leaving this behind, the railway runs through deep rock cuts for seventy miles, as if the Titanic forces of the rocks were to be seen in greatest power, just before the prairies were reached.

Arrived at Whitemouth, the land began to be arable, and though wet and swampy at times, cheered up the spirits of the traveller and his companions. He had travelled from North Bay a thousand miles westward through continuous rocks, of which he did not know even the names or composition, but which he was quite sure would not give a living for a sheep much less for a man. It is this thousand mile expanse, with another thousand miles east of North Bay, extending parallel to the St. Lawrence River until it reaches Labrador, and with some hundreds of miles of width from north to south—a barren rock-region known as "The Laurentian Island—the basis of all Canadian as well as American geology—that we shall describe in Chapter I.

Meanwhile our traveller having reached his destination—Winnipeg—and gone out to see the prairies in their brilliant dewy August, we shall proceed to discuss the more prosaic subject of the terms to be employed in this work.

B.

EXPLANATION OF THE TERMS TO BE USED.

BOULDERS—or Erratics are lumps of stone of varying size and composition, generally larger than a man's fist, which have been rounded by the action of ice or water, or by interaction on one another.

PEBBLES—Small rounded pieces of stone, of a few ounces in weight, formed in the same manner as boulders.

GRAVEL—A name generally applied to pebbles of limestone, or other rocks, mixed up with the pulverized material.

CONGLOMERATE—A mass of rock, made up of small boulders or pebbles, cemented into a mass. It may be of any variety of rock material.

BRECCIA—A conglomerate, with the cemented rock-fragments angular, they not having been subjected to continued action of ice or water.

GRANITE—A rock mass of deep subterranean origin, once molten and now exposed, and made up of the three different minerals, quartz, feldspar and mica, next to be described:

(a) *Quartz*—A mineral of siliceous composition, many colored, hard enough to scratch glass. It includes such varieties as flint, rock crystal, amethyst, cairngorm, etc. Sand is pulverized quartz, and sand beds consolidated into rocks are called sandstone.

(b) *Feldspar*—A hard often flesh-colored or white mass made up of alumina, with potash, soda or lime. It is when crushed and subjected to the action of running water the source of clay, and from clay the useful metal aluminium is obtained. Ordinary clay is a very impure mixture containing particles of sand, lime, etc. Shale and slate are hardened beds of fine clay.

(c) *Mica*—A shiny, lustrous, often transparent, but variously colored mineral, of soft consistency, found in fragments in granite. It is often composed of silica. alumina, potash, iron-oxide and water.

METAMORPHISM—When rock material, finely divided, is deposited in layers in rivers, lakes or seas, the beds are called strata, (singular, stratum). When these beds are afterwards subjected to great heat and pressure from below, they are changed in hardness, consistency and color. This action is called metamorphic.

Gneiss—(pronounced gnice). Is simply granite and other rocks altered by heat, pressure and shearing to a crystalline, laminated rock.

Syenite—is a granitite rock made up of the two components, hornblende or mica and potash feldspar.

SCHISTS—Metamorphic rocks showing the effect of pressure in the arrangement of minerals in parallel positions.

TRAP—A comprehensive name, given to deep formed or even volcanic rocks, made up chiefly of silica, alumina and feldspar, but of very varying composition.

HORNBLENDE—A silicate containing alumina, magnesia, lime and iron oxide. A fibrous variety is called asbestos.

PYROXENE—A mineral varying from white to dark green and black; a silicate of lime and magnesia, sometimes with alumina and iron.

DIORITE—A rock made up of hornblende and lime or soda feldspar; is sometimes called greenstone.

DIABASE—and gabbro, the dark colored crystalline rocks in which lime—soda feldspar are always present; are often known as trap rocks.

TALC, soapstone and serpentine are rocks which may be cut with a knife; they are commonly greenish in coloring, shading into other colors. In composition they are hydrated silicates of magnesia.

TUFF—Rock consisting of consolidated cinders or scoria.

GRAPHITE—Plumbago or black lead. A soft black mineral—a form of carbon—supposed to be obtained by metamorphic action. (Anthraconite is closely related to it, being a mixture of graphite and limestone).

LIMESTONE—Of many colors and varying consistency, made up of lime and carbonic acid. The carbonic acid is produced in volcanic rocks, and also is breathed out by animals. Limestone is of several varieties:—

(a) *Crystalline limestone*—A hard variety found in volcanic and metamorphic rocks. A valuable form of this is marble.

(b) *Calc spar*—A sharp angled crystal mass, scratched by a nail, at times crystallizing into Dog-tooth spar.

(c) *Calcareous Tufa*—When water with carbonic acid and lime (lime carbonate) in solution runs over a bed of moss, the lime is deposited on the moss and often forms great porous rock masses. This is often called simply Tufa. It is also known as Travertine.

(d) *Fossiliferous limestone*—Along shores where lime rocks are being deposited, remains of plants and animals are often imbedded. Such remains in the rocks are called fossils, and they give their name to the limestone.

(e) *Chalk*—Which gives its name (Lat. creta) to the Cretaceous formation of England is lime carbonate, and is chiefly made of minute shells—or ooze found in the deep sea.

(f) *Marl*—A mixture of lime and clay; the lime is often pulverized masses of sea shells.

GYPSUM—Often white or yellow, easily cut with a knife. A compound of lime or calcium and sulphuric acid; often found with beds of rock salt. There are several varieties:—

(a) *Selenite*—Crystalline and pearly in lustre and often splitting into thin leaves, found in large quantities at certain points in Saskatchewan.

(b) *Massive*—In certain localities found in the form of thick clay-like deposits; is ground up to make cement or to be used as manure. White and pure masses of this gypsum are known as alabaster.

(c) *Plaster of Paris*—When by heating gypsum water is driven out from it, it is called plaster of Paris. When crystalline gypsum separates into transparent layers like mica, it is distinguished from mica by (1) being less elastic and by breaking when bent quickly back and forward; (2) by producing around itself when placed upon a hot stove a small pool of water.

APATITE—Calcium phosphate—used as a fertilizer when pulverized.

IRON—Found in all formations, seen in brown and sometimes iridescent colors given to ponds and often deposited on the rocks. Five chief iron compounds may be named:

(1) *Magnetic Iron ore*—Black, magnetic iron oxide, either crystalline, in masses, or often in pulverized form. The magnet attracts it.

(2) *Hematite*—A reddish, iron oxide; has a red streak. Red ochre is the earthy variety of this ore.

(3) *Clay iron stone*—A massive iron carbonate found in the clay layers above the coal, often in nodules of clay.

(4) *Limonite* or Bog iron ore is an impure variety of iron oxide found in swamps.

(5) *Iron pyrites*—A compound of iron and sulphur, useless as iron ore, but used for manufacturing sulphuric acid.

COPPER—

COPPER PYRITES—Copper, iron and sulphur, a valuable ore of copper.

BORNITE—A variety known as erubescite or variegated copper ore; a richer compound than copper pyrites.

NATIVE COPPER—Pure massive copper.

ALKALIES—Various salts found in the soil in Western Canada, and also at times giving a distinguishable taste to the water, locally go by the name of "alkali." They are the same as are found in sea water, and are:

(1) *Sodium chloride*—Common salt. Found as rock salt or in brine springs.

(2) *Sodium sulphate.*

(3) *Sodium carbonate.*

(4) *Calcium chloride.*

(5) *Magnesium chloride.*

(6) *Magnesium sulphate*—Epsom salts.

(7) *Calcium sulphate*—Gypsum.

COAL—Chiefly carbon with earthy impurities. Its varieties will be described in Chapter VI.

PETROLEUM—A liquid mixture of various highly-combustible hydrocarbons.

MALTHA—Mineral tar. A solid substance made by an overflow of petroleum, from which the volatile oils have evaporated, and left a thick layer of combustible matter. Found in the Mackenzie River district.

OTHER GEOLOGICAL TERMS.

EROSION—The breaking down of rock or soil by the air, river or sea.

DENUDATION—The clearing away of the broken material, stone and earth by water or other agency.

ESCARPMENT—An abrupt cliff or rock face.

FAULT—The drop of a portion of bed rock from it natural place, showing a movement of the beds on either side of cracks or crevices.

DYKE—An intrusive mass of rock, coming up through cracks in the crust and often extending for a long distance through stratified rocks.

TERRANE—A district or extent of country having some features in common.

GLACIER—A great mass of ice accumulated on a mountain height during a long period, and which as a tongue of ice is slowly sliding down the valley.

MER-DE-GLACE—(Ice field). The larger part of the glacier which is constantly accumulating new ice within the region of perpetual snow.

CREVASSE—A great crack in a glacier, made as the glacier is slipping downward.

MORAINE—The accumulation of boulders, gravel, sand, clay, etc., lying in front and along the flanks of the glacier, as it tears out and crushes the rocks in its course.

ROCHES MOUTONNEES—Glaciated hummocks of rock that have been rounded by the ice and where protruding above the soil rudely resemble a sheep's back.

STRIAE—Scratches made on rocks by glacial action.

DRIFT—The soil, often stony, that has been transported by the ancient glacier or the glacial waters.

A LIST OF NAMES GIVEN BY GEOLOGISTS TO THE STRATIFIED ROCKS FORMED IN SUCCESSIVE PERIODS OF TIME.

NOTE:—The names given are those adopted by the Geological Survey of Canada. The lowest are the oldest, but the spaces do not represent proportionate periods of time.

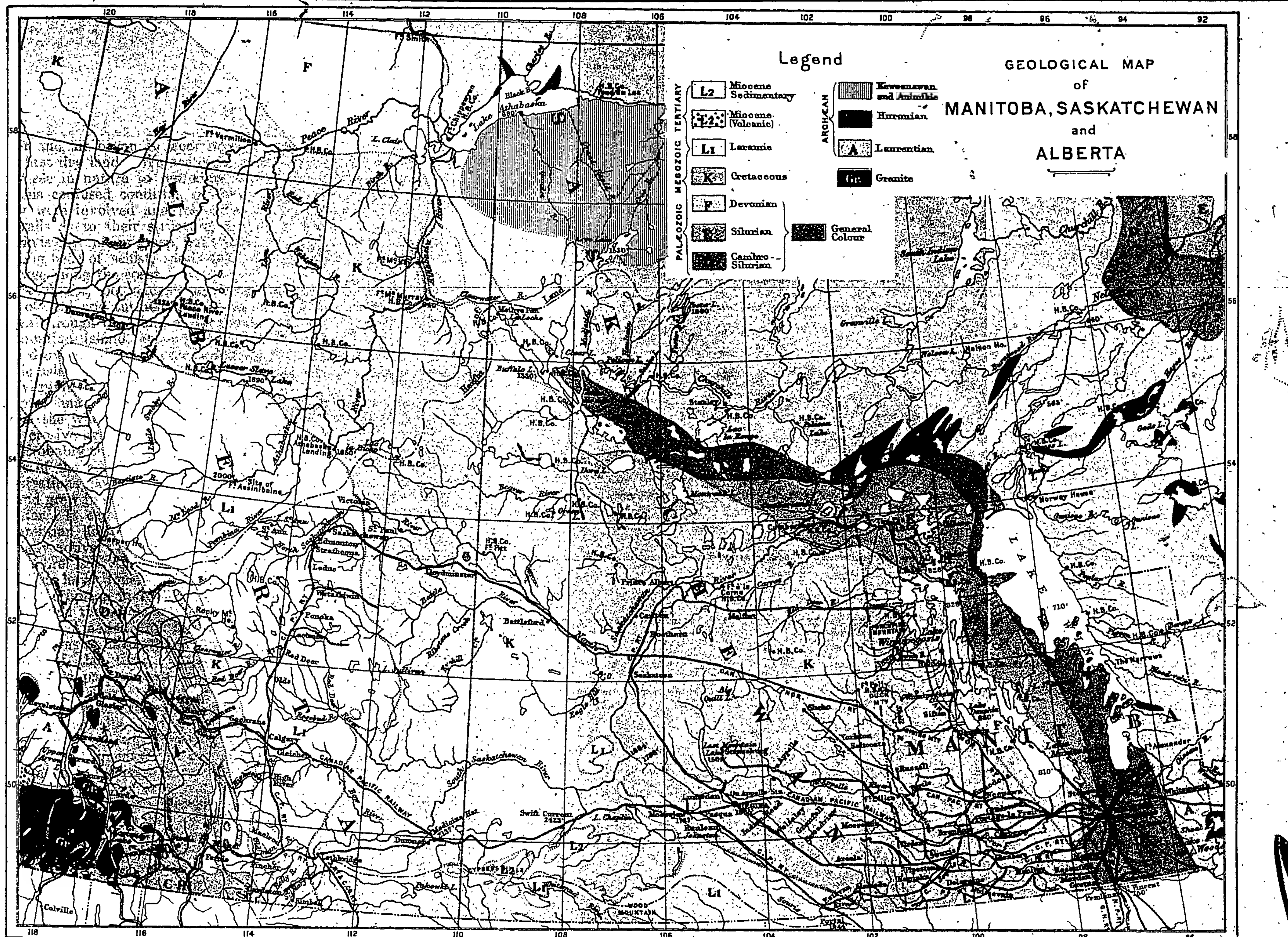
Quaternary	Recent Post Glacial Glacial	
Tertiary Cainozoic (New Life)	Pliocene Miocene Eocene	Laramie (Eocene–Cretaceous)
Secondary Mesozoic (Middle Life)	Cretaceous Jurassic Triassic	
Primary	Permian Carboniferous	None in Manitoba
Palaeozoic (Ancient life)	Devonian Silurian Siluro-Cambrian Cambrian	
Primitive Eozoic (Dawn of Life)	Pre-Cambrian Huronian	
Archaean (The Geological beginnings)	Laurentian	

CHAPTER I.

THE LAURENTIAN ISLAND.

It was a great event when untold ages ago the Almighty fiat went forth that the dry land should emerge from the sea of waters. It was no doubt a slow movement growing out of a superheated chaos containing the elements, some seventy in number, of which Chemistry now tells us. These were all commingled in a vaporous state, and by the loss of heat which was being given off into space and by combinations forming liquid components, came in some cases into a more solid consistency. By the cooling and union of the two gases which make it up water was formed, first as steam and afterwards as liquid, but still boiling hot. The chloride compounds were formed and have ever since been companions of the water, preserving with their antiseptic power the sea water. As cooling took place the granite mass of the Laurentian gradually solidified, volcanic matter of other combinations of elements followed and new substances rose, seething, spouting and fuming in the deep, but too hot yet to be solid, and too hot to afford a habitat for plant or animal unless it were some of the Bacteria—microscopic plants—with their heat resisting powers. At last the granite island, small at first, became the nucleus for the present Laurentian Island which gathered to itself, from beneath, the substance and material from which all subsequent rocks have been formed. This Laurentian Island was thus with two smaller islands the foundation of the whole of North America. As already referred to in the introduction, this Laurentian region extends two thousand miles from east to west, stretching from the Coast of Labrador to the western prairies, and extending northward in places to the Arctic Sea. It was originally a broad V having Hudson Bay in the opening, and with from end to end an elevated backbone ridge called on the eastern side the Laurentian Mountains. It continued as a height of land parallel to the shore of Hudson Bay and, at a distance from the great lakes on the south, to the far north. Originally this island with a mighty spur running down through the Thousand Islands and continuing to the Adirondack Mountains of to-day, represented the largest part of the continent of North America. Thus Canada's rocky inheritance gives her a priority on the continent.

Ages after land and sea were thus marked out, the enormous evaporation of moisture and the return of this as mists and rain, led on towards the present state of things, and the agency of



Reprinted from map compiled by James White, F.R.G.S., Geographer, Department of the Interior

river and air began to wear down the granite mass which was the first dry land. We are quite unable from any processes we now see in nature to reproduce in statement what took place in this confused condition of things. Strata were formed, but they were involved and folded, so that no satisfactory theory prevails as to their structure, and even the question of their origin is beyond our grasp, but the worn down granites did become folding beds of schist, sandstone, etc., and the island began to enlarge along the coast.

No doubt, too, volcanic agency did its full part in this terrible era of heat and turmoil and desolation. The sea water soaking down through the pumice and porous rocks on the skirts of the Laurentian Island, encountered great heat which expanded it, and drove up through cracks and openings, great masses of volcanic ashes and dust. Some geologists reasoning from the cases of Vesuvius and Etna, maintain that the amount of volcanic erupted matter distributed about the steaming island would equal the whole amount of material obtained by the denuding and erosive agencies already spoken of.

Probably the case of the Island of Iceland, from which thousands of the people of Western Canada come, is one of the best illustrations possible of the manner in which the Laurentian Island grew in extent. Iceland is entirely composed of volcanic matter. It came up in the North Atlantic Ocean as did the Laurentian Island. Its great volcano Skaptar, has been especially active. Since the Christian era it is said to have poured out more lava than the great volcanoes Etna and Vesuvius together have done. The volcano, Skaptar, had a particularly violent eruption in 1783. Much hot steam and great clouds of ashes filled the whole sky. Volcanic dusts in vast rolling circles fell upon America and the atmosphere of England and of all Europe was so filled with cinders that alarm settled on the whole people of the time. Hundreds of recorded eruptions have, during the past history of Iceland, added to the bulk of the island.

Thus, through fusion and denuding agencies producing sedimentary deposits, and through volcanic eruptions, the early Canadian Island was formed, not as later beds which were deposited as sedimentary rocks in layers and then passed through metamorphic agencies, but by the fusion of the first rocks into the general basis of eruptive rock which now appears as gneiss. To a young Canadian geologist, Mr. A. C. Lawson, belongs the honor of originating this refusion theory now generally held as to the Laurentian and Huronian rocks.

The rocks over the vast extent of the Laurentian Island are generally red, gray and banded feldspar, hornblende or mica, or pyroxene gneisses, (See pages 13 and 14). One of the most

important species of rocks found in well marked zones, are the original limestones, which, with the lime feldspars when ground down in after ages, supplied the material for the limestone rocks of Manitoba.

No fossils are found in the rocks of the Laurentian, though various suggestions of organic remains having been found have been made, such as the Eozoon of Sir William Dawson, but these are now generally believed not to be fossils but simply a peculiar mineral structure in the rocks. It is sufficient to consider the local conditions of enormous heat on the Laurentian island in its formative period to see that the existence of life was practically impossible.

The geological map shows that the Laurentian island juts for only a short distance into Manitoba. It is contained in a truncated triangle, whose western side begins near the south east corner of the Province on the Lake of the Woods, and goes northwestward till it strikes Lake Winnipeg, whose eastern shore it then follows to the northern boundary of the Province. This area may be said to include about one-eighth of Manitoba.

The slope of this Archaean region of Manitoba is southwestward, and down this declivity for ages the forces have operated which produced the subsequent formations found in Manitoba. The slope from the Lake of the Woods to Lake Winnipeg gives a fall of more than three hundred feet, and down this declivity dashes the fierce Winnipeg River, thus connecting the two great bodies—Lake of the Woods and Lake Winnipeg. As shown by the hundreds of observations of the striae or scratches, made long ages after the youth of the island, by agencies which we shall describe, the proof is afforded that the Laurentian Island is the great store house from which were obtained the vast materials which have gone to build up much of our North American Continent.

CHAPTER II.

THE HURONIAN ORE-BEARING ROCKS ON THE LAURENTIAN ISLAND.

WHILE the erosion and levelling down of the Laurentian Island has never ceased but has continued to the present day, yet the period which immediately followed the formation of the Laurentian Island was a most interesting and important one. These rocks were formed along the sea coast line of the island, and also on the margins of the lakes and watercourses. From rocks of this second period having been first studied along the shores of Georgian Bay, part of Lake Huron, they are known as the Huronian, although west of Lake Huron the corresponding rocks are called by other names which we shall mention. The Huronian rocks are of intense interest to some, and are of national importance, because they contain metallic deposits of gold, silver, copper, nickel, cobalt, etc. Like the Laurentian rocks, they contain no fossils. The completion of the Huronian rock formation seems to have been marked by a marvellous period of volcanic eruption throughout the wide extent of the newly-formed deposits. Being shore-line beds, the Huronian deposits were much looser in consistency than more ancient rocks, and their schistose character made the intrusion of volcanic dykes and veins easier and more general. Among the Huronian rocks the more usual varieties are quartzites, with quartz and jasper conglomerates, slate conglomerates, flinty limestones, and earthy rock containing volcanic ash, and numerous pebbles of Laurentian rock. Stratified diorites abounded especially near Lake Huron. Some idea of the length of time taken to form the Laurentian and Huronian deposits may be given when it is stated that Sir William Dawson calculated that the depth of the former is some six miles, and of the latter nearly three and a half miles. The mind staggers when, judging by the rate of the formation of rock beds to-day, it considers the length of time which was taken in depositing a perpendicular depth of nine or ten miles of rock. The agglomerates and tuffs give frequent evidence of the volcanic intrusions in the rocks, but the feature of the rock beds is to splinter and push up into thin layers. The interest in the Huronian formation chiefly centres in those rocks having veins and dykes which contain rich mineral deposits. Fifty years ago along the north shore of Georgian Bay, great deposits of copper ore (copper pyrites and bornite) were discovered. That these have, though not continuously, been largely worked is shown by the heaps

of debris lying in their neighborhood. At times, when the price of copper was low, these mines languished, yet at present much effort to develop them is being made by American capital. Going northwestward from the Bruce Copper mines of Georgian Bay, enterprising prospectors came in the Sudbury region upon large deposits of nickel which have been successfully worked. Northwestward from Georgian Bay and Lake Nipissing, in the Temiskaming region, another mineral district of this formation has been opened by a colonization railway, and in what is called Cobalt district, large deposits of silver ore have been found. It may be safely presumed that these points scattered over the same formation of narrow Huronian, but at considerable distances from each other, are not deposits stumbled on by accident, but are indications of a vast mineral wealth in the Huronian rocks which our agricultural visitors entirely fail to conceive of, much less to grasp.

In the region about Thunder Bay on Lake Superior, attention was early called to rocks allied to the Huronian, here known as the Animikie rocks, and to indications of silver in their veins. On the lakeward side of Thunder Cape, a marvellously rich pocket of silver ore was worked on Silver Islet, and no less than $3,250,000 worth of ore was mined and sold. A persistent impression prevails that there are other silver deposits in the region of Thunder Bay. In the broken region west of Lake Superior, partly in Canada and partly in the United States occurs the Atitokan or Iron range, which gives promise of great results in the future production of ore. This ore is being carefully examined.

To the west of this point along the water courses leading to the Province of Manitoba on the shore of Rainy Lake and Lake of the Woods, proof is given by actual working of large deposits of gold associated with a certain percentage of silver. In the quartz and other veins that have been widely prospected mines have been opened. It may be said that the gold distributed in these Huronian rocks is of the low grade character, but the experience of more than fifty years crushing and treating of such ore in Nova Scotia as a remunerative industry shows that we only need the introduction of capital and skilful management to make our Rainy Lake and Lake of the Woods ore deposits a valuable possession.

The great extension of railways in late years in Western Canada in the Canadian Pacific Railway, Canadian Northern, and Grand Trunk Pacific Companies and by the Temiskaming Railway, has led to the opening up of the mineral resources of Canada, and the further building of these lines is almost certain to acquaint us with new mining districts. The geologist has found the Huronian rocks and described their features, he has made maps

on which are marked their occurrence; it now remains for prospectors to examine these rocks, and for capitalists to look into their development, for while mining enterprises have a large percentage of loss, yet there is a fair working return for the money carefully invested. A narrow strip of Huronian rocks occurs near Lake of the Woods on the boundary of Manitoba, and it is known that superincumbent deposits of the Huronian rocks are to be found on the Laurentian rocks skirting the east shore of Lake Winnipeg in the province of Manitoba, more especially on Black Island. The pre-Cambrian or Upper Huronian rocks are maintained by some to have indistinct organic remains, and may perhaps include the Animikie and Keewenian deposits on Lake Superior, but they are largely undetermined.

CHAPTER III.

THE FIRST PRAIRIE BASIN IN MANITOBA.

WE have thus far dealt with the Archaean rocks, including the Laurentian Island, and have noted points where the Huronian is distributed upon it. The Archaean region occupies, in Manitoba, a triangle with its western side running from the southeast corner of the province, and continuing northwesterly till it strikes about the southeast corner of Lake Winnipeg, from which point it follows the east side of Lake Winnipeg, to the northern boundary of the province. On this western shore of the Laurentian Island ages ago the open sea rolled. Indeed we know that the floor of the ocean for a thousand miles and more to the west was of Laurentian rock. We know this because portions have been found in the Rocky Mountains thrown up long ages afterwards, and elevated thousands of feet. But the processes of deposit, the carrying down by water of rocks and debris, chiefly of clay and limestone, followed the slopes of the Laurentian Island. The sea water dissolved the earthy salts and lime and the less soluble fragments were spread over the shallows with the coarse parts near shore. Then followed a slight sinking of the island and the sea crept over what had been dry land, meanwhile the sea water began to give up its lime. Then was formed the limestone belt which we are now to describe under the name of *the first prairie basin or steppe*. The bottom of the sea from the eastern boundary of Manitoba to past the Selkirk Mountains in British Columbia, became encrusted with a series of successive layers of lime and the shells and bones of many generations of sea animals which then lived and died. The same story could be told of the south side of the Laurentian Island in Ontario, in the region between where Toronto and Kingston now stand, in New York State, in the State of Michigan and elsewhere. Those who have lived in a "hard water" region will understand the capacity of water for carrying lime. They have only to look at the bottom of their tea kettle to see the crust of lime. Railway engineers also have much trouble from the crusting of their locomotive boilers. While it is likely that vegetable and animal life had existed before this period, yet the temperature of both water and rock was so great that no certain traces of either remain on the Laurentian Island. However, in what geologists call Palaeozoic seas, plants and animals both grew, some of them in the animal kingdom as high up as the lobster of modern seas and great numbers of the cuttle fish family

swam the seas. Large numbers of worms, many of them provided with shells which are preserved, lived, while vast numbers of corals built their reefs. It is the remains of these and other animals occurring in the limestones and shales of this period which enable us to identify our rocks as of the same age as those of Toronto. The animals along the shores were almost entirely marine, and so on dying were covered over by the enveloping mud deposits, which after being changed into hard rocks encased their prisoners for all time. The rocks of this first prairie basin in Manitoba are largely limestones, but at times shale and sandstones appear. The rock deposits from the east at Whitemouth to near Portage la Prairie—about a hundred miles—belong to this period. This Palaeozoic belt may be seen on the map to run southward into Minnesota and Dakota, and to pass northward on both sides of the Lake Manitoba beyond the boundaries of Manitoba, even into Arctic regions. True, the rocks are now generally covered over with the drift or soil, but here and there exposures occur which enable us to judge of the character of these rocks which lie in layers and are nearly horizontal. The formation may be seen on the bold cliffs on the west side of Lake Winnipeg, at the Tyndall quarries, at East Selkirk, St. Andrews Rapids, in the Rosenfeld well borings, at Little Mountain, Stony Mountain, Stonewall and largely on the shores of Lakes Manitoba and Winnipegosis. Numerous wells have reached through the drift to these rocks. An examination of these rock exposures and a study of the fossils have enabled us to identify and arrange the strata of this region into the following:

Devonian
Silurian
Siluro-Cambrian
Cambrian

Pre-Cambrian
Archaean.

Beginning first with the oldest and lowest of the Palaeoroic we have:—

1. *Cambrian*—While there is a general belief that these rocks are revealed in the boring of the Rosenfeld well, they can scarcely be said to be yet determined. Large areas of Cambrian are believed to exist in Northern Saskatchewan on Lake Athabasca.

2. *Siluro-Cambrian*—These rocks are found in most of the localities in the region mentioned, lying east of the Red River. However, Stony Mountain also belongs to these rocks. Two of the most notable divisions of these rocks in the neighbor-

hood of Toronto are the Trenton and the Hudson River series. The same formation is distinguishable among these rocks of the Red River District. A remarkable well bored one thousand feet deep by the Canadian Pacific Railway, at Rosenfeld, some fifty miles south of Winnipeg, has given a complete view of the rocks of the Siluro-Cambrian of the Red River Valley. These rocks abound in fossils. They are largely used as the building-stone of Winnipeg and of many other places in the Canadian West. As the natural gas elsewhere is frequently found to originate in the Trenton rocks, trials have been made in the rocks corresponding to them in Manitoba. but thus far without success.

3. *Silurian*—On the west side of the Red River in Manitoba a very thick and almost unbroken deposit of drift covers the limestone rocks. Hence from the west side of the Little Mountain and Stony Mountain, exposures not far from the city of Winnipeg, stretches a region of say thirty miles, not yet certainly determined, but likely to be classed as Silurian in age. There seem certain indications west of Stonewall of rocks similar to the Niagara series, a well known division in Ontario and Michigan of the Silurian rocks. Some thirty or forty miles west of the city of Winnipeg a strip runs from Lake Manitoba southward, where salt was formerly manufactured, from which salt springs spring and almost certainly indicate the Salina or Onondaga series of the Silurian rocks lying above the Niagara. This strip crossing the Sale River is marked by salt springs from which the half breed residents of Rupert's Land made salt. The line is marked further southeast by the water being salty, until Rosenfeld well on being bored was found to be an artesian well throwing up a stream of brine. As is often the case gypsum is associated on the shores of Lake Manitoba with the occurrence of salt. The gypsum is of the massive variety, and is now being extensively manufactured for cement and for building purposes.

4. *Devonian*—The upper division of the Palaeozoic rocks found in Manitoba is the Devonian. This extends in the line of Winnipeg, from a point probably forty miles west of the city for some twenty miles to the town of Portage la Prairie, where it is a thin layer lying upon an Archaean ridge, which rose above the Silurian sea. Though narrow at this point the Devonian rocks run northwestward and widen out, being largely exposed in Lake Winnipegosis and continue a broad band even to Mackenzie River and the shore of the Arctic sea. Large deposits of petroleum are found in the far north in this formation, but thus far, though search and boring have been diligently tried, no such discovery has been made in Manitoba.

Palaeozoic elevation—Now after long ages in which the sea

coast of the Laurentian Island has been covered in the tropical seas of the time with superimposed beds of rock full of vegetable and animal remains, a steady movement of upheaval took place in the Laurentian Island, lifting also a belt over a hundred miles wide of the Palaeozoic rocks which had been steadily forming. Had this movement ceased when the rocks just reached the surface of the sea, great lagoons and swamps might have been formed and coal would have been deposited at a time when coal-formation was proceeding in Nova Scotia and Pennsylvania. But it was not to be. For ages the Palaeozoic fringe of the Laurentian Island was above the sea level and was the plaything of the sun and wind and storm.

CHAPTER IV.

THE SECOND PRAIRIE STEPPE IN MANITOBA AND SASKATCHEWAN.

It may be well to speak here of the similar history through which what is now the basal portion of the Pacific Coast rocks passed. Undoubtedly at the time in which the Laurentian Island was formed, an island which we may call the Pacific Island, of similar granitic and afterwards gneissoid characters, came into existence. As already said, the floor of the sea a thousand miles and more to the west was of the same Archæan rocks. During the time of Cambrian, Siluro-Cambrian, Silurian and Devonian rock formation around the coast of the Laurentian Island, rocks of the same mineral and fossil characteristics were being deposited in the far West. An observer at Banff in the Rocky Mountains will pick up to-day fossils of the same kind as he may find at Stony Mountain near Winnipeg. Consequently we may expect in the two islands the same history except that the Pacific Island remained somewhat longer under the sea, and received a deposit of Carboniferous rocks though no coal. However, both were at length elevated and stood for ages separate, the homeless sea from Portage la Prairie to Calgary having full sweep between them. An era of continent-building known as the Cretaceous period of the Mesozoic age, now set in with wonderful power. The ocean water was shallow and far from clear, but the animal remains are in great contrast to those of Palæozoic time, having as they do bright and shining shells. From the cliffs of the Laurentian and Pacific Islands great quartz and gneissoid rocks were torn up and crushed and carried down to the ocean and to the southward were deposited great beds of sand upon the shores. The geology of Western Canada now differed entirely from that of Ontario, for no Cretaceous rocks are found on the Devonian shores of the latter. The activity of the forces of nature of the Cretaceous period seems to have been amazing and the age produced rapidly the vast sand and shale beds—measuring together perpendicularly a thickness of thousands of feet. No doubt the Cretaceous seas between the two parts of the future continent were often shallow. A marked difference between the Palæozoic and Mesozoic rocks is the higher animal remains in the Cretaceous rocks. Remains of well-developed fishes, beautiful examples (with highly colored shells) of the cuttlefish family ; bones of great reptiles that dominated the Cretaceous seas ; genera of toothed birds ; and vast numbers of minute animals making up

the deep sea ooze are found, while the plants seem to be those largely of modern types. So much does this age introduce the animals and plants of the present day, that the question is at times debated. Are we still in the Cretaceous period ? During the time of formation of the Cretaceous rocks there appears to have been a period of great instability. At times over a particular period estuarine and fresh water conditions prevailed, showing a shallow coast, while at other times a great subsidence took place and wide areas of its land were in the deep sea. On the slopes of the Pacific Island, both in the regions of the Crow's Nest Pass and on the west side of the Pacific Island, where Nanaimo and Comox now are, at times coarse conglomerates and at other times beds of sand and shales were formed, having buried in them extensive remains of fossil plants. These were in areas little above the sea level in swamps. The vegetation in these being tropical, consisting of ferns, tree-ferns, club mosses and the like, was deposited in masses and became beds of coal. As to the changes which took place afterwards in the coal, notice will be taken in Chapter VI. The coal beds of the plateau east of the Rocky Mountains may be said, however, never to have been disturbed from their horizontal position, thus showing an absence of volcanic action.

The elevation of the eastern escarpment of the Cretaceous rocks is a matter to be dealt with at a later stage, but it may be stated that the line of elevation is one of the most marked features of the Manitoba terrane. Where the prairie basin averages some 800 feet above the sea, the second steppe runs up to 1,200. The prairie basin is not more than fifty miles wide at the boundary line, Red River being the lowest portion of the trough. The headland so well marked west of Morden called Pembina Mountain, rising several hundred feet above the valley, runs northwestward; it is followed up by Tiger Hills. A great valley, whose origin will be explained later, comes through the escarpment, and down this opening the Assiniboine River runs. The discussion of the Assiniboine Valley is one of the most interesting points in Western Geology, and will be fully treated in Chapters VII. and IX. Lake beaches are resumed on Beautiful Plains near Arden and Neepawa, continued on the considerable elevation of Riding Mountain, and seen still further running northward in the Duck Mountains. These heights are largely covered with drift. At several points, however, the Cretaceous sandstone shows itself.

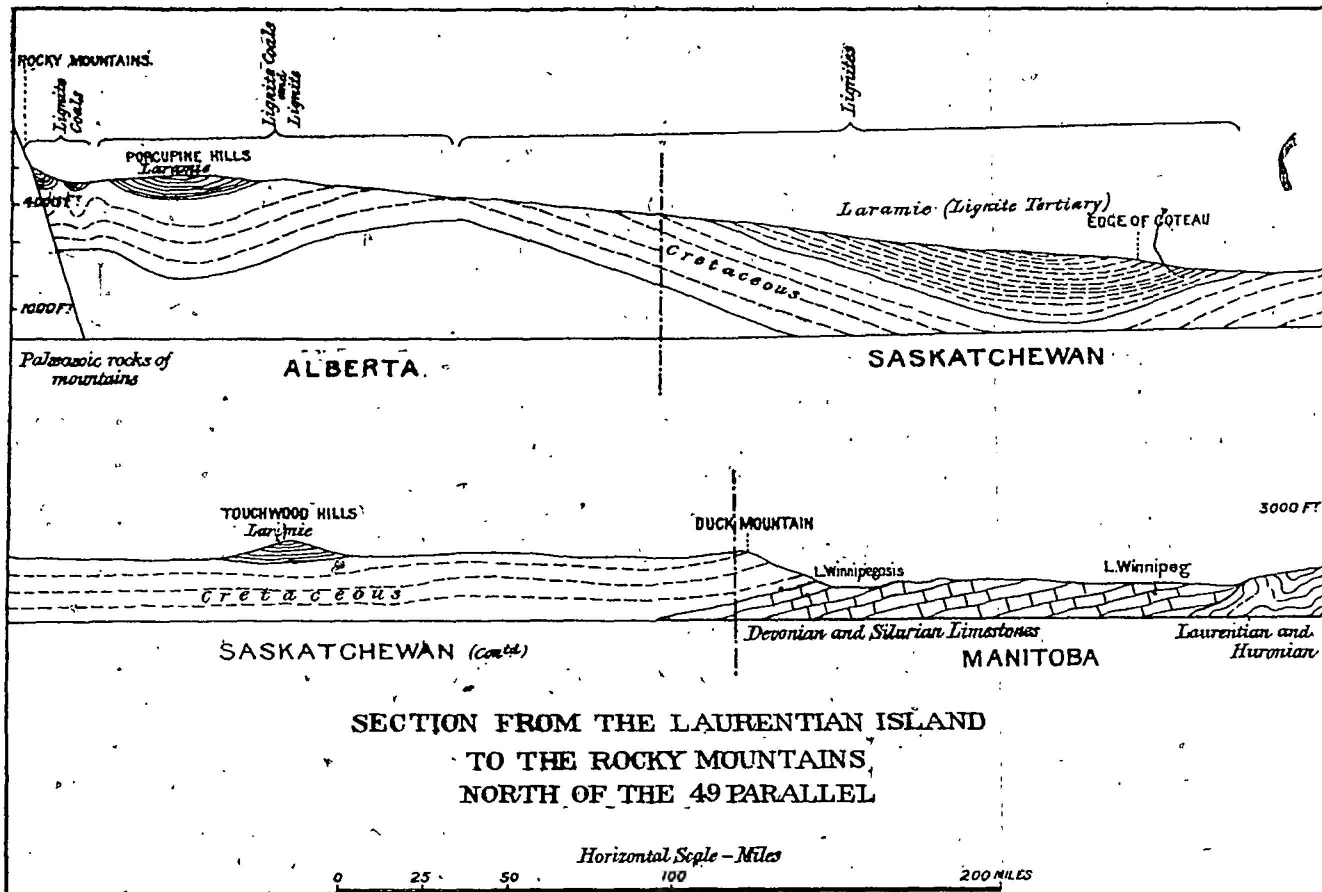
CHAPTER V.

THE THIRD PRAIRIE STEPPE IN SASKATCHEWAN AND ALBERTA.

THE Cretaceous beds were thus completed but the time for their general elevation had not yet come. However, in certain parts, as already stated, great depressions took place, especially in the portions nearer to what we have called the old Pacific Island. Many of these depressions were filled with fresh water, and the new formation usually called the Eocene, belonging to the Tertiary, was formed. The contrast between the junction of the Cretaceous and Tertiary in America and that in Europe is one of the best known fields of discussion in geology. In England the chalk beds belong to the Cretaceous period and really give the name (creta-chalk) to them. For many ages the Cretaceous of England was raised above the sea and its growth checked. At length its time for depression came. It had, being soft, become largely honey-combed, caverned and weathered by the denuding agencies. The new beds of the Tertiary which were deposited upon it were at different angles of bedding and had to fill up all the crevices. This state of things is represented by saying that the Tertiary beds were "unconformable" to the Cretaceous.

In the Canadian West and in the Western States it is entirely different. The beds of the Tertiary conform to the beds of the Cretaceous. A new difficulty, however, arises in the study of the western rocks. The great gap in Europe gives a completely different collection of plant and animal forms in the two formations. In the Canadian Tertiary, growing as it does without a break out of the Cretaceous, there is an intermediate zone containing "the remains of vertebrate animals which bind it firmly to the Cretaceous period of the Mesozoic rocks;" but another author says that "the vegetation is unequivocally Tertiary." The meaning of this is plain. The remains of fishes, turtles, dinosaurs, and other great reptiles such as crocodiles, etc., occur here as they had done in the Cretaceous rocks, whilst on the other hand the fresh water shell fish and fossil trees are found in great abundance. Such trees as oak, willow, poplar, beech, elm, maple, hickory, fig, redwood and the like, thoroughly characteristic of modern times, are embedded in these rocks. But whether Cretaceous or Tertiary, the most important feature to us of this Laramie formation is that it is a coal formation, containing the Lignite, which is largely used for fuel in different parts of the Canadian West. The same variety of coal is found at Glei-

chen, east of Calgary. Leaving behind the lignite-bearing beds chiefly in Alberta, we come after a considerable interval of distance, eastward, to deposits of quite a large area of lignite. These are found in the south eastern part of the Province of Saskatchewan. They also belong to the Laramie formation. One very interesting fact remains. An outlier of the Laramie rocks is found in an isolated elevation in southern Manitoba known as Turtle Mountain. This is on the east side of the Souris River, and is given as an evidence of the great denuding force of the Souris River, which has cut out all connection between the real Souris deposit and this lonely isolated mass. In this Turtle Mountain outlier, lignite beds have been found ; they have the distinction of being the only coal deposit known to exist in the Province of Manitoba. While the elevation of this third steppe, like that of the second, belongs to a later geological movement to be described, yet it should be said that a very marked elevation is met with at less than three hundred miles west of the Pembina, Riding and Duck Mountain elevation, at what is called the Coteau (Fr. hill). A height of 1,500 feet is reached. At Calgary the level is upwards of 3,000 feet above the sea. It will thus be seen that commencing at Red River there is a continuous rise till the foot of the Rocky Mountains is attained.



SECTION FROM THE LAURENTIAN ISLAND
TO THE ROCKY MOUNTAINS
NORTH OF THE 49 PARALLEL

CHAPTER VI.

THE COAL AREAS.

THE Canadian West has no coal of the Carboniferous period. Carboniferous rocks on the Pacific Island, as we have already stated, it has in abundance, but they were all of a deep sea deposit on the island coast, and containing coral, crinoid and other animal remains consolidated these into hard limestone. There was no coal. The elevation of land took place too rapidly to allow in the Carboniferous time for coal formation in lagoons or swamps. But in the later Cretaceous time, fortunately for Western interests, the coal period came. The question of coal-formation has given rise to much difference of opinion, but it is one of continual interest. There are undoubtedly estuarine deposits of coal in France where water-logged driftwood sank and deposited material sixty or seventy feet deep which afterwards became coal, but it is now pretty generally agreed that in most cases coal is produced from vegetable material in swamps, which are alternately overflowed by sea or lake and then elevated for a time above the water. The coal forest was a dense, luxuriant, tropical growth. The coal of all regions shows the same vegetable content of low, quick-growing plants, especially horse-tails, mosses and ferns. Great trees with curious diamond-shaped markings on their bark sank their odd-shaped roots into the oozy soil, while a relative of the pine tree, having, however, parallel-veined leaves, rose in greatest profusion to the height of twenty-five feet. The animal remains found in the coal measures are few, though fossilized wings of insects which frequented the swamp lands, are found. In some cases the coal was formed in the swamp where the trees grew, in other cases by plants drifting from the adjoining land. The alternation of conditions of growing vegetation and flooded areas is represented in nearly all coal deposits. Most commonly the bottom of the swamp, which produces the vegetation, was clay. This clay deprived, by the vegetable growth, of its alkalies and iron is called fireclay, and is much used for pottery and brick-making. Frequently in the West it is found hardened into shale. The growing forest continued its deposition of vegetable matter for centuries. On this deposit being covered by an overflow of salt or fresh or brackish water, of which traces are seen in the animal remains, a new layer of mud took place and this killed the vegetation and crushed it into a mass. The decaying plants gave off carbonic acid, which penetrated the overlying mud and laid hold of the iron in the clay, thus producing nodules of clay-iron stone, which

are found abundantly in this overlying layer. The clay deposits dried and hardened into shale. At times sand deposits intruded and formed beds of sandstone. The alternation of fireclay, coal seam and shale bed containing ironstone, in the same order, and repeated eight or ten times over in a depth of one hundred feet, has led to the comprehensive name—"The Coal Measures."

SECTION OF STEEP RIVER BANK OF BELLY RIVER. (LETHBRIDGE).

		ft.	in.	
1.	From top of bank to No. 2	149	6	
2.	Finely laminated grey shale	8	0	
3.	*Coal* (Shaly below)	1	6	
4.	Grey, thin bedded shale	12	0	
5.	Ironstone	0	3	
6.	Grey shale	1	9	
7.	*Coal*	0	8	
8.	Early shale and nodular sandstone, carbonaceous below	7	0	
9. Main Seam	*Coal*	1	4	Coal 5′ 4″
	Shaly parting (often almost absent)	0	4	
	Coal	4	0	
10.	Carbonaceous shale	2	0	
11.	Grey shale	2	0	
12.	Ironstone	0	4	
13.	Greyish and brownish shade	3	0	
14.	Carbonaceous shale	3	0	
15.	Coaly shale	0	8	
16.	Grey shale	2	0	
17.	*Coal*	0	4	
18.	Carbonaceous shale to water	1	4	
		201	0	

The Coal Measures of the Cretaceous rocks give us our oldest coal in the West. Accordingly we find that the farther down in the coal bed or the farther back in age the coal is the better it usually is. The Lethbridge, Tabor, and the Crow's Nest Pass B.C. mines represent the best coal. The latest coal period, the Laramie of the Tertiary Age, placed by some in the Mesozoic Age, is a remarkable era. So great is its deposit of coal that some geologists are disposed to call it the Lignite formation. This includes the enormous deposit of coal made in the district south of Edmonton, in an oval some hundred miles from north to south and a hundred from east to west and further supplemented by the Souris deposits of the same period extending from near the base of the Missouri Coteau eastward, and reappearing in the

Turtle Mountain outlier. This coal is lignite and has veins mined in large quantities at Hassard, Bienfait and Roche Percée. It is not coal of first quality, but in southeastern Saskatchewan, southwestern Manitoba and on the Winnipeg market it is sold largely as a cheap coal. The enormous glaciation which took place in the period following the Laramie is marked by various facts worthy of notice. Two hundred miles east of Turtle Mountain in the northeastern Minnesota the drift contains numerous fragments of lignite. The writer saw large specimens of it in the hands of an old prospector, Alexander Baker, a resident of Rainy River. The Roseau River, running from this Minnesota district, has frequent pebbles of lignite in its waters. So too with the Pembina River which runs eastward from the Turtle Mountain district. The contour of the lignite-area leads to a strong presumption that vast areas of this Tertiary coal region were scarified by glacier action and the material carried far away from its original place of deposit. The diagram on page 34 confirms this view. The only Anthracite yet known in the West is that of Banff district, but this belongs to the Cretaceous period, though by folding, heat and pressure it has been altered in quality and consistency.

COMPARISON OF WESTERN COALS.

All analyses of coals are reduced to percentages of contents such as water, volatile matter, fixed carbon and ash. In the same coals the water and ash may vary considerably so that comparisons of analyses might be misleading. Take for example some such coal as this which could come from the mines of Canmore:

	Water	Volatile	Fixed Carbon	Ash
Run of-mine coal.......	1.7	12.0	72.0	14.0
Same coal washed......	4.0	13.1	78.6	4.3

The second coal is not so dry but has lost its ash to a great extent. It is still the same coal and its fuel ratio is expressed by the following fraction; $\frac{\text{fixed carbon}}{\text{volatile}}$ has remained the same, *i.e.*, $\frac{72}{12} = 6$, and $\frac{78.6}{13.1} = 6$. If we then class the coals by this ratio we have the following:

			Fuel ratio
Anthracite	coal—Cretaceous from	Anthracite and Bankhead	8 to 11.6
Semi-anthracite	" — " "	Canmore	6 " 8
Bituminous	" — " "	Coal Creek, Fernie	3.3 " 4.7
"	" — " "	Blairmore, Coleman	2.7 " 3.3
Lignitic	" — " "	Lethbridge	1.26 " 1.38
"	" —Laramie (Cretaceous) from	Edmonton	1.34 " 1.49
"	" —Laramie (Cretaceous) from	Red Deer River	1.33 " 1.41
Lignite	" —Cypress Hills		1.05 " ....
"	" —Wood Mountain		1.0 " 1.10
"	" —Souris River		.82 " 1.10
"	" —Turtle Mountain		.90 " 1.00

CHAPTER VII.

THE ROCKY MOUNTAIN UPHEAVAL.

By the Rocky Mountain Upheaval is meant a series of changes, by which, on what we call the Pacific Island great elevations and depressions alternated until at length the Rocky Mountains were raised to their present height. Later geologists concede that there is a constant movement and folding in the earth's crust, hard and unyielding as the solid rock may seem. The earth as it gives off its heat into space, contracts and crumples up on the surface, like a baked apple when it cools, having its surface covered with furrows. Elevation takes place largely from the pressure inward from the sea. Dana, the great American geologist, accounts for this by the fact that masses of earth-deposit piled along the shore, crush in upon the land and thus folding, faults and cracks are produced—that thus elevations and depressions take place. As already stated there is a regular deposition of stratified rocks through the whole Palæozoic up to the Jurassic period. During this lengthened period, a slight subsidence was all that took place in the Pacific Island. Now came great upheavals for a time, but again the island subsided and continued to remain so through the Cretaceous period, during which time no less than 9,000 feet of strata were deposited. The broad gulf stretched between the Pacific Island and the Laurentian Island. While these islands with their strata of Palæozoic rocks lay above the sea their shores were receiving great deposits. There were as stated nearly two miles deep of Cretaceous rock. This mass largely filled up the gulf, especially along the Pacific Island.

The Cretaceous rock being completed, then came perhaps the most tremendous rising of the land that the Western Hemisphere ever saw, leading to nothing less than the enormous fracture of the Rocky Mountains and the Andes along the whole earth from north to south. The Cretaceous rocks lately submerged in the sea were forced to the top of a mountain range. On the west side of the Pacific Island a similar mountain range appeared. Great heat acting upon the rocks changed them and a notable occurrence took place in the coal beds, which we have seen were formed in the Cretaceous rocks. This action may be judged of from the coal deposits found in the Bow River Pass, west of Calgary. There the lately formed coal was upheaved, subjected to pressure in the grinding of the rocks and acted upon by the great internal heat from below, so that the bituminous coal was changed to anthracite, which we know as "stone coal"—hard, stony and

brittle—but not so heavy as the Pennsylvania anthracite, which is of a greater geological age.

The movement which elevated the Rocky Mountains to their high eminence had also raised the table land which we have called the third prairie steppe, and at the same time the second prairie steppe to a lesser elevation. Thus from Riding Mountain to Kananaskis Pass the height above the sea is now from 1,500 to 4,000 feet. From the coal beds not having been disturbed in the prairie deposits of the Cretaceous which have been described, the movement seems to have been a long continued but effective upward one, so that the Rocky Mountain range would appear to be the line along which the mass under strain gave way, and is thus really a rugged earth-crack running from north to south.

In these slowly-rising table lands under consideration, depressions, as was natural, occurred at different points. Great lakes filled the hollows in this now elevated terrane, and mountains were formed in the later Tertiary. The deposits along the lake shores—generally called lacustrine—were abundant, for the agencies of air and water were carrying down detritus from the mountain sides. Great masses, chiefly of sandstone rocks, such as are found at Calgary and eastward also at Roches Percées were thus formed, those at Calgary making an excellent and substantial building stone. More interesting still were the beds of lignite coal, which we now find widely distributed. The mountains and elevated plateau thus grew to their completeness. This period also seems to have been accompanied by volcanic action of a very decided kind, especially in the more mountainous districts to the south. In the west lavas poured out over a great space on the Pacific slope. Traces of active volcanic action have now almost disappeared from the more accessible parts of the Rocky Mountains, though the hot springs at Banff and elsewhere are still found.

CHAPTER VIII

THE GLACIAL PERIOD.

We have now to deal with one of the most remarkable occurrences which ever took place in our geological history, viz : the coming in the northern parts of both continents of a period of intense cold and the consequent formation of great fields of ice. The Tertiary age had, even in the farthest regions of the north, a somewhat tropical climate. England had in the later part of the Tertiary age been tropical, and even Greenland, which is to-day the abode of ice, had in the Cretaceous period, growing on its remote wastes, forests of trees—cinnamon, magnolia, eucalyptus, laurel and the like. It is true that even in the previous Miocene period there had been indications that the temperature of the northern climates was beginning to lower, so that at the close of the Tertiary came a time which has come to be distinctively known as the "Ice age."

We have scarcely time to seek very earnestly for some way of accounting for the extraordinary fall from a tropical to an arctic climate, even as far south as 40° N. in North America. Many theories have been advanced as to this. One is, that a change took place in the great arm of sea which extended from our present Gulf of Mexico to the Arctic Sea. The rising of the land and the depositing of sediment filled this up and prevented the warm water of the tropics reaching northward, and thus modifying the climate of the Arctic regions as it had formerly done. The objection to this theory is that while this may have had some effect, yet the same Arctic conditions prevailed in the North of Europe without any such cause to influence it. Others have held that an elevation of several thousand feet in the north of the continent would as in the case of a high mountain give an arctic climate. This is plausible, but there seems no evidence, that such general elevation over the whole of North America and Europe took place at this time. Indeed, from the great upheaval of the Rocky Mountains having just been completed, such a mighty uplift in the north seems very unlikely. The widespread ice-invasion from the north over the plains, and its encroachment on territory so far south as 40° N. in North America, seems to need some astronomical explanation by which the continuous deviation of the pole of the earth from the perpendicular to the plane of its orbit, which now makes the difference between the heat of summer and cold of winter, made a general decline in the rate of temperature so great that in the north for long centuries the era of continual ice prevailed.

The condition of things even now to be seen at the Canadian Pacific Railway station of "Glacier," in the Selkirk Mountains, a point where the railway bed is five thousand feet above the sea, is worthy of notice. Here in a most picturesque spot we are entirely surrounded by mountains whose tops reach up 13,000 feet above the sea. High up on the slopes of these may be observed deposits of snow and ice. Along the whole line of a mountain range to the east may be seen a mer-de-glace, or sea of ice, which extends for many miles. This is perpetual ice. When snow falls on the mountain tops it is deposited in the ice field, but cannot melt and is incorporated with the older ice. On the heights even the summer heat makes little impression. These high mountain tops are in the Glacial period now. Further down in a sloping valley, but connected with this frozen mountain, comes a tongue of ice, which as we ascend the valley, presents a precipice-front to us eighty or a hundred feet high on a perpendicular. This great solid mass extends backward and upward and is connected with the lower part of the mer-de-glace. The mighty tongue of ice which you are viewing is called a "glacier." Should you visit it in summer you will find it melting away below and a violent, muddy glacier stream gushing out from beneath it as it recedes. This glacier is found to be sliding down the valley at the rate of a few feet a year. If you scale a mass of gravel and boulders on one side of it you can look upon the top of the glacier. There you will see wide cracks in the ice, running from side to side, no doubt caused by the ice cracking as the front of the glacier slips down the incline. Each of these cracks is called a "crevasse." The mass of stones and debris on which you are standing is very interesting. You are reminded by the arctic plants growing among the stones that you are near a great block of ice which makes a climate highly northern. This heap of detritus, rising up as it does in keeping with the level of the moving ice, is called a "moraine." On examining the moraine it is found to be composed of the same material as neighboring rocks on the mountain side over which the glacier is creeping. The enormous weight of the glacier has crushed to powder masses of rocks which now are largely sand or clay; sometimes it has broken up rocks into the larger masses and these rolled down are called boulders. Here is nature's workshop—or crushing mill—where the rocks are being prepared for various uses when they are carried down by the stream to be spread as a layer of sediment or soil on the floor of the lake. At times in Switzerland great masses of the glacier or of the ice-field lose their hold and come dashing down the slope carrying before them whole villages. This is called an avalanche. Down the valley below the glacier are sand flats formed by the water; beds of clay are also so found. Then the chief components of the broken rocks are carried out into the lake or river according to

their specific gravity, the lighter being taken out the further. Sometimes hundreds of white gneiss or quartzite boulders are seen deposited down the valley from the glacier and look like a flock of sheep lying here and there. These have the name in consequence of "roches moutonnees." The glacier is the great soil-maker of the earth. Should a mass of ice break off at once from the glacier and fall into the sea as it does at the Muir glacier in Alaska, the floating mass of ice is called an iceberg. Icebergs carry southward in their course great quantities of detritus.

Now during the long time called the "Glacial period," there was not only here and there a glacier but the whole of North America from shore to shore and down as far as the latitude of 40° N. was one vast ice field. It is estimated by some geologists that an ice-cap six miles high extended from coast to coast on this continent. This, it is said, was of so great a weight that it crushed down the earth's crust below it and lowering the ice made it more subject to the sun's rays so that beginning at the south near 40° it gradually melted away and the icy finger of winter was slowly withdrawn further and further north. The southern sloping valleys were filled with the ice as it came gently slipping southward, until each valley had its tongue of ice or, as it is called, "ice-lobe." The moraine material was gradually carried down in the milky stream which emerged from the ice lobe, and the clay was deposited far away in the bottom or on the shore of some lake or river. Slowly mother earth resumed her own and the glaciers receded to their proper home on the mountain side in the far north. It is generally agreed that the glacial period prevailed for many thousands of years. There seems to have been a very long period of icy rule; then there came a warmer time when the icy grasp was driven far northward. Afterwards there followed another glacial period and it completed much work left undone by the first ice period. The mild intermediate period of time is sometimes called the "Interglacial period."

CHAPTER IX.

THE INLAND LAKES.

WHATEVER may have been the causes of the formation of deposits of ice in the Glacial period, the results are very marked. The close of the Glacial period and the return of higher temperature to northern regions constituted the glacial ice a tremendous crushing agency in covering the rocks with soil and making a country fully able to supply the wants and appeal to the imagination of the intelligent farmer with whom we began our western journey. Wherever there were depressions, the melting ice filled them with water and formed great lakes in which the soil made from the pulverized rocks was distributed by various agencies. The situation in Manitoba and Eastern Saskatchewan was exceedingly picturesque and in the high levels of the second and third prairie steppes it was equally so. In the three prairie steppes we see that the slope is northern. The height of land lies to the south in the neighboring states of North Dakota and Montana. This seems to have been the case in pre-glacial times. The old channels of the Red and Assiniboine Rivers and of the great Saskatchewan were as at present and the outlet of the Nelson River to Hudson Bay existed in Tertiary times.

But when the vast ice cap from ocean to ocean formed, miles high, then this northern downflow ceased and the ice masses formed a firm barrier across the north. In consequence of this in the lowest levels, the ice from the north when it began to melt poured its waters into a great depression bounded on the south by the height of land running south of the Lake of the Woods and through the States of Minnesota and North Dakota at the head waters of the present Red River. The height of land was some 300 miles south of the city of Winnipeg. A wide sheet of water rose, probably five or six hundred feet deep where Winnipeg City stands to-day and actually emptied itself for a time southward into one of the tributaries of the Mississippi River. This enormous body of fresh water partially held in on the south by the height of land and on the north by the ice barrier, extended far east of Lake of the Woods and westward to the Pembina Mountain, the Riding Mountain and Duck Mountain, thus reaching above Brandon City, and extending far up the Saskatchewan River. It contained far below its surface the present lakes Winnipeg, Manitoba and Winnipegosis, and was 110,000 square miles in area—a prodigious lake, greater than the five great lakes of North America, Superior (31,200 square miles), Huron, with Georgian Bay (23,800), Michigan (22,450), Erie

(9,960), and Ontario (7,240)—the five aggregating 94,650 square miles. Its drainage area covered half a million of square miles. To this Glacial lake, Prof. Upham, of St. Paul, gave the name Lake Agassiz, in honor of Prof. Agassiz of Harvard University, the great apostle of the Glacial Ice Theory in Geology.

To the west of this Lake on the second prairie steppe at the same time as Lake Agassiz overspread the first prairie steppe, were two other great lakes produced by similar causes, to which the names Lake Souris and Lake Saskatchewan have been given [illegible] glacialists. Though not thus far clearly traced it is entirely likely that on the third prairie steppe and even far north in the Mackenzie River basin hemmed in by the Rocky Mountains on the west, the highlands to the south and the ice dam on the north, other glacial lakes existed and were of service in scattering the glacier products and spreading them over the Cretaceous and Tertiary rocks of the region. The details of Lake Agassiz are more fully worked out by the geologists than are those of the western lakes; but no doubt they are very similar in result. As the earth after the first fierceness of the glacial cold began to regain its former heat, the ice dam steadily but slowly gave way. A period arrived when the water began to follow the old natural channel down the Lake Winnipeg water course to Nelson River, and ceased flowing southward to the Mississippi. For long periods the water stood at a fixed level and on all the containing heights of Pembina Mountain and Riding Mountain a well marked beach line was formed. For thirteen successive stages as the northern channel became more and more free, these beaches were deposited. They can be traced with ease to-day along the slopes of Pembina Mountain. One peculiar thing about these beaches is that they are not horizontal but are higher as we trace them northward. Some have sought to explain this by the theory that the water stood higher in the lake by being attracted by the ice dam as approach was made northward to it. This seems unlikely. The more reasonable explanation is that while the lake was gradually lowering, the land northward was rising more rapidly than that farther south.

But the part of this strange story most important to us is that in these lakes as the glaciers poured down their waters and washed down their moraines, and broke off ice-bergs laden with detritus, a coating of boulders, and deposits of clay and sand were being made on the Palæozoic limestones in the first basin and on the sandstone and shale rocks in the second and third prairie steppes. To these agencies as we shall state more fully in Chapter X., are we indebted for the drift or soil which covers our fertile plains. By the glacial lakes Agassiz, Souris and Saskatchewan, with the rivers connecting them we explain many of the most perplexing problems of our surface geology.

(a) Evidences of Glaciation.

One of the most interesting things in viewing the smooth western slope of the Laurentian Island in Eastern Manitoba, or the limestones in the neighborhood of Stonewall, is the occurrence of striæ or scratches made in some cases southwestward and in other cases southward on the surface of the rock. These were made in the path of the glacier as it ground its way downward. Hundreds of such striæ have been recorded as occurring on the Laurentian Island. In Stonewall the limestone rock is now reached some six or seven feet below the surface of the soil. Several houses have their cellars dug to the flat rock. If milk or water be spilt at one corner of the cellar it will follow the striæ running to the S.S.E.

(b) Leaving Outliers.

At times great masses of rock are left behind by the glaciers and stand as monuments to-day. This happens at Stony Mountain, a mass of rock rising some sixty feet above the prairie, thirteen miles north of Winnipeg, having an abrupt escarpment on its west side and a sloping declivity on the east. The theory of this is that the Stonewall glacier coming S.E. met the point of the glacier which was coming S.W. on the east side of the mountain and that by this impact of forces the so-called mountain escaped. The west side of Stony Mountain supplies one of Winnipeg's quarries.

(c) Limestone Boulders.

Long ago observing men noticed that although the shores of Lake of the Woods were all of Archæan rock, that yet in the bottom of the lake there were found numerous considerable pieces of flat limestone. At first it was supposed that they came down Rainy River, but no limestone could be found in that direction. It is now evident that the limestone blocks came from near Lake Winnipeg. When it was made out that Lake of the Woods was within the borders of Lake Agassiz and that Red River was in the same lake it was plain that water or ice action was sufficient to transport these rocks over the hundred miles of distance between the two.

(d) Ozar and Coteau.

Six or eight miles northeast of Winnipeg is found Bird's Hill, a great mass of gravel and boulders continuing for miles along the ridge known as Moose Nose Hill. On being examined, the Bird's Hill deposit is found to be unstratified. In it also great masses

of clay or loose rock are found confined. It was long an object difficult to explain. Now it is believed that it was a great mass of gravel and detritus, tumbled on top of a portion of the glacier, that this mass of ice had been detached, had perhaps become an iceberg in Lake Agassiz, and had on being deposited melted away throwing down the detritus in a great heap without order or form. It is known as an *Ozar*. On the west side of Red River southwest of Stonewall is a well marked ridge or coteau of the same class.

(e) Other Glacial Lakes.

Two and probably more glacial lakes west of Lake Agassiz, being farther south and earlier freed from the ice-cap, poured their waters down the slope northeastward.

Lake Souris.—Nearest of these to Lake Agassiz but on the second prairie steppe was Lake Souris, seemingly a much smaller lake than Agassiz. It ran northward from Turtle Mountain, its eastern limit reaching near to Killarney and then northward to Langvale (or Lang's Valley). It then swept round to the south of Brandon hills, northwestward to Alexander and north of Griswold and Virden. Into this the Assiniboine formerly flowed and deposited its delta to be still seen in the sand hills of Virden. A glacial lake known as Lake Dakota seems to have poured waters into this lake from the southwest. The west side of Lake Souris probably ran up northwest past the sources of the Pipestone River.

From this lake two rivers originally carried the waters down to Lake Agassiz; these were the Sheyenne River in Dakota and the Pembina River, of whose course we shall speak further.

Lake Saskatchewan.—On the second prairie steppe another large glacial lake existed. This was seemingly bounded by an enormous moraine, west of the "Soo" line running from Portal to Moose Jaw. This Missouri coteau or moraine as it is called, is a remarkable mass of confused and irregular clay deposits and alkaline salts, having no drainage running through it, but about thirty miles across, being known locally as the "badlands." At the base it has risen 150 feet higher than the prairie at the foot of the Turtle Mountain. The height of this coteau above the sea is about 2,000 feet. The line of this moraine, no doubt the result of marvellous glacier action, is toward the elbow of the South Saskatchewan. It would appear as if at this point, where the South Saskatchewan turns northward, that river emptied into Lake Saskatchewan, which we are about to describe. Not far from this point the Qu'Appelle River begins. Here there would seem to have been a delta for there are sand hills. At times in high water we are told by alarmists that the Saskatchewan in spring may come pouring down the Qu'Appelle, flood the Assini-

boine and produce bad results. There is no possibility of this as there has been a decided lowering of the bed of the Saskatchewan, at the elbow, and below the Qu'Appelle River. For some miles west of this height of land small rivers have run into the South Saskatchewan. Carrying on northwestward the coteau is traced to Eagle Hills and then further northwestward. The length of the coteau is said to be 800 miles. Somewhat connected with this morainal deposit is the elevation of drift materials found in Moose Mountain and Touchwood Hills, which appear to be only earthy elevations in the prairie. The line which we have been tracing of the Missouri coteau is evidently the western shore of the great glacial Lake Saskatchewan. Like Lake Agassiz it opens out to the north, having had the ice dam at its northern barrier. Receiving the South Saskatchewan, Lake Saskatchewan evidently emptied itself by way of the Qu'Appelle River and the Assiniboine River into which the Qu'Appelle falls. Lake Saskatchewan may have had another exit southerly into Lake Souris. The Assiniboine then flowed southward into Lake Souris.

ALBERTA LAKES.—Probably other glacial lakes were also formed. A small one existed in Manitoba north of Brandon Hills. In regard to the lakes of the third prairie steppe, covering a part of Alberta, the plan has not yet been made out. In Southern Alberta broken territory exists, seemingly draining southward to the Missouri. The conditions of lakes in Northern Alberta were probably similar to those of the lakes now described.

(f) SANDHILLS ; AND THE CHANGE OF RIVER COURSES.

Any visitor to Manitoba going westward from Portage la Prairie to Brandon will see many miles of sand hills, consisting of shifting sand, held down here and there by grasses or white spruce trees, but carried about very easily. This land is useless for agriculture and is now made a reserve by the Dominion Government. The same thing is seen to the south side of the Assiniboine at Cypress River and Glenboro, and near Walhalla, North Dakota. Between Oak Lake and Virden occur sandhills also. Near the elbow of the Saskatchewan as well as elsewhere they are found.

These dunes were long a subject of difficult explanation. The existence of Lake Agassiz and the fact that the Assiniboine in its later history came from the far west where it received the Qu'Appelle and other rivers, has thrown light upon the problem.

(a) The Assiniboine was first a tributary of Lake Souris. As the level changed, Lake Souris could not discharge its waters down the Pembina as it had done, and so cut its way eastward from Alexander through the intervening soil overlying the Cretaceous rock making an entirely new channel—a new Assiniboine.

Pouring into the broad and quiet Lake Agassiz, the river deposited its sand in the still water, and the sand made a great delta in the lake when it was at its height. Afterwards when Lake Agassiz subsided, the Assiniboine, like an unnatural mother, cut its way through the sandbeds it had created, and made its present channel. It is remarkable that between Douglas and Chater the river entirely cleared away the sand and left the original clay deposit which had been formed. The sandhills are the old delta.

(b) THE SOURIS RIVER.—Lake Souris formerly emptied itself by the Pembina River. A channel called Lang's Valley is to be seen down which it flowed, but the opening of the Assiniboine valley and the channel of the Souris which lowered the lake, left a height of land which prevented its continued use, and the flow from Lake Souris was, in its diminished form of River Souris, forced northward and at length found its way into the Assiniboine some eighteen miles below Brandon.

(c) PEMBINA RIVER.—The height of land cut off the connection with Lake Souris, but still a flow from the eastward slope of this elevation found its way down a series of lakes well known in Southern Manitoba as (1) Pelican, (2) Lake Lorne, (3) Lake Louise, (4) Rock Lake, (5) Swan Lake, all connected by the river. Leaving Swan Lake the Pembina River running without interruption curves into North Dakota at Walhalla, N.D. It at first fell into Lake Agassiz, where a great delta was formed represented by the sand dunes of Walhalla. Since the fall of Lake Agassiz, the Pembina River in later times has forced its way to the Red River, entering it now near the boundary line at Pembina.

CHAPTER X.

THE DRIFT FORMATION.

In speaking of the Drift Formation it is usual for recent geologists to separate it from the more usual formation of soils. Soils are sometimes produced by the disintegration of rocks by atmospheric agencies as may be seen on the chalk downs in England, where a foot or two of soil have resulted in past ages from rain, frost, wind and the chemical agency of oxygen in the air. Such soils as these are also found in Tennessee in the United States. Again another production of soil is found in the deposits of mud along creeks or rivers. These are usually spoken of as alluvial deposits.

In Canadian Geology the term drift is confined to the earth-formation made by glacier or iceberg. We have already seen how enormous are the results which have followed in the inland lakes of Western Canada from the ice action.

Among Geologists two schools have existed even as to the comparative importance of glacial and iceberg action. Those born by the sea, as the late Sir William Dawson, and accustomed to the iceberg deposits making the banks of Newfoundland, have naturally regarded the action of icebergs as more important, but those accustomed to the phenomena of continental ice as viewed by the late Professor Agassiz of Harvard University, who was a native of Switzerland, naturally see in a great glacier like that of the Aar, the agency for crushing the rocks and supplying the material for the drift deposits. The gigantic operations which have been carried on upon the Laurentian Island and in the thousand miles from this Island to the Rocky Mountains, have led all Western geologists to identify themselves with the glacialists as led by Agassiz. The great Missouri Coteau, a mass of detritus 800 miles long and 30 miles wide seems impossible on the iceberg theory, although this had been advanced to account for it ; but it becomes reasonable when looked upon as a moraine of a great glacier. The disposition of the Drift deposit through the agency of the glacial lakes described, is attributed to the time of the disappearance, by the advent of greater heat, of the great ice-cap of North America. Observations taken at the Niagara Falls, the Mohawk River, the south of the Laurentian Island, and the Minnesota drift of the upper Mississippi River—which last is derived from the Laurentian Island, or as some late American geologists would call the western side of the island the Kewatin glacier—have led the majority of geologists to at-

tribute the Drift formation to a period about ten thousand years ago, although some demand a longer time. At that time as the glaciers receded northward, they deposited their great earth-burdens over the land as well as in the inland lakes, where they were spread over the lake bottoms. These deposits, consisting of boulders, gravel and finely divided soil sometimes known as till, were spread by currents from point to point. Such materials have been traced hundreds—even a thousand miles—from their place of origin. The rocks thus crushed and spread were not only the crushed material of the Laurentian gneisses, but the limestones, sandstones and shales of the later rocks. The drift varies greatly in depth according to local conditions. As a rule the lowest layer lying on the rocks of the Palæozoic age in the Winnipeg valley or on the Cretaceous and Tertiary rocks of the second prairie steppe is made up of boulders; next is often a mixture of boulders and clay, then a considerable layer of blue clay. Then comes a bed of marly clay, known locally as "white mud." In among these are often distributed beds of sand and gravel. Above this succession of drift formation deposits, in most parts of the country, is found an overlying layer varying from one to six feet of "humus," or loam, largely of vegetable origin. This will be treated under the heading of "Soil" in Chapter XII. The following are examples of the soil and drift in different parts of Western Canada:

BORINGS IN DRIFT FORMATION OF WESTERN CANADA.

First Prairie Basin.

Winnipeg.
Well No. 4

1 Loam	2
2 Marly clay	6
3 Blue clay	30
4 White sand	1
5 Gravel	4
6 Boulder clay (hard pan)	1
7 Gravel	3
8 Boulder clay	6
9 Gravel	1
	54 feet
Rock (limestone)	

Rosenfeld.
56 miles S. of Winnipeg.

1 Loam	4
2 Fine silt or clay	111
3 Sand and gravel	10
4 Boulder clay	12
5 Boulders	6
feet	143
Rock (shale)	

Second Prairie Steppe.

Solsgirth, Manitoba.

130 miles northwest of Winnipeg

1	Loam	2
2	Hard blue clay and gravel	42
3	Hard blue clay and boulders	10
4	Hard yellow boulder clay	12
5	Softer bluish clay	16
6	Softer bluish clay	74
7	Layer of sand with water	—
8	Blue clay with boulders	136
		292 feet

Rock (shale).

Regina, Saskatchewan.

357 miles west of Winnipeg

1	Clayey soil	3
2	Very dark sticky clay	27
3	Sand with small pebbles	10
4	Black sticky clay	13
5	Sand, red to black	18
6	Black clay	10
7	Sand (dark like 5)	4
8	Reddish clay with small pebbles	13
9	Sand, dark and fine	—
	feet	98

Rock

Third Prairie Steppe.

Langevin, Alberta.

695 miles west of Winnipeg

1	Clay loam	30
2	Quicksand	7
3	Clay	12
4	Quicksand	10
5	Clay and sand	9
6	Quicksand	7
7	Clay	8
8	Quicksand	5
		88 feet

Rock (sandstone)
Natural gas is found here.

Cassils, Alberta.

733 miles west of Winnipeg

1	Dark clay loam	2
2	Yellow clay	10
3	Blue clay	40
	feet	52

Rock (Shale)

CHAPTER XI.

WATER SUPPLY.

FROM the study of the conditions connected with the formation of the drift, the reader may see that it is not a matter of the witch-hazel method of finding water, nor of any occult process. The water poured down by the rain, or resulting from the melting of the snow or ice is the source of our water supply either on the surface or in the depths of the earth. In desert or arid countries the lack of rainfall makes the finding of water a difficult thing. But in almost all parts of the Provinces of Manitoba, Saskatchewan and Alberta there is a considerable rainfall—in many parts an abundant supply. In those districts called the "Irrigation districts," there is not enough of rainfall, but even these regions have cycles of years with sufficient rain. When this prevails there may be retained subterranean supplies sufficient for constant use if obtainable. The source of water then is in permeable beds such as beds of sand, loose layers of shale, or harder rocks with crevices or reservoirs in them caused from faults in the beds or in the openings between the drift and the underlying rock. From the surface rainfall the water finds its way between or through underlying layers into lower rocks. By the channels mentioned it is distributed and as the sand or other permeable beds are reached, the pressure of the rocks will drive the water toward any part where an opening is made.

When the method of formation of the drift layers is considered, it will be seen that there is a liability, at times, of sandy, friable or permeable beds being wanting and in such a case there may be in any country waterless districts. After a pretty full examination of different parts of Western Canada, it may be said, that it is surprising to find how few regions there are, where there is arable land, which have any deficiency of water beneath them. The principles governing the existence of a water supply are quite simple, but there are a number of applications of these principles which it may be well to examine:

(1) LAKES AND RIVERS.

To the former occupants of the land—the Indians—creeks, rivers and lakes, the natural water supply, was available and satisfactory. By the early settlers also settlement took place along the rivers, and one of the chief reasons for this was the easy access

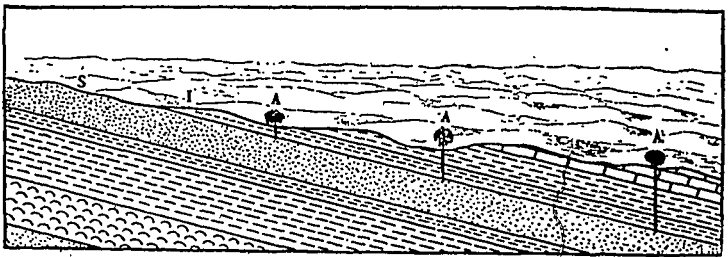
to water. The greater rivers and lakes of the country have palatable water which, in a sparsely settled country, might be deemed sufficient.

(2) WELLS.

The advent of a denser population or the settlement of the country more systematically, renders the river supply inadequate. Thus digging or boring for water has become a necessity. Two classes of wells are thus obtained :

(a) Surface wells. The fact that in many parts of the country the drift beds are only 60 or 100 feet in thickness generally gives the hope of striking a water bearing bed at a comparatively short distance from the surface. Sometimes eight or ten feet are sufficient to get a supply, though usually not an abundant supply of good water. However, by digging eighteen, twenty or thirty feet the desired stream is found, and may be obtained by pump or bucket. At times sixty feet is required.

(b) Artesian wells. The artesian well does not arise from any new condition from that of the surface well, except that there is a greater pressure upon the bed of the water supply which drives the water up to the surface of the ground or even to make a spouting well several feet above it. It is evident, however, that the artesian well may on being drawn upon become weaker and become simply an ordinary pumping well. The general explanation of the artesian well is given by the following diagram, in which a large surface exposure of permeable bed supplies pressure enough to drive the water up to the surface :



ARTESIAN WELLS.

The system of Winnipeg water supply is that of a series of flowing wells. At Winnipeg, which has 100,000 people to be supplied with well water, three large wells are sunk some 18 feet in diameter. These are over an area of some three or four miles. They are dug through the drift to the limestone rock, some

50 to 70 feet. On account of the pressure of the water reached on approaching the rock, it must be kept back by compressed air. The force of the imprisoned water is so great that when allowed to flow it will undermine the rocks. In consequence of this it has been found necessary to insert pipes imbedded in concrete in the bottom of the wells. The city, by these three wells in operation, has a daily supply of three and a half millions of gallons of water, and two additional wells being sunk will greatly increase the present supply. The water not having reached the air till it is taken out into the pipes is cold, is absolutely free from organic matter, and is of about fifty degrees of hardness. The water is softened by lime, is filtered, and a coke burning carbonic-acid apparatus is used to complete the softening of the water. This reduces it to about sixteen degrees of hardness, the standard of the water of North London, in England.

(c) Springs. Depending on the same general principle of water supply as the surface well or artesian well, occurs the "crystal spring," of which the poets speak. When across the sand bed containing the water supply a valley or break in the layering passes, the water trickles out from the exposed bank as a brook, or forms in a hollow as a great spring. It is kept fresh by the continued flow from the sand bed. At times a sufficient number of springs are obtained in a hillside to combine in forming a reservoir to supply places of some size in population. Frequently springs of this sort soaking through beds of iron form chalybeate springs, through quartz siliceous springs; sulphuric acid in gypsum beds makes "sour springs"; or if affected by sulphuretted hydrogen, sulphur springs appear. These often form an incrustation of sulphur on their margins.

(d) Surface reservoirs. In certain districts of the several Provinces which are waterless, a device which has been sometimes followed is to excavate in the earth reservoirs one or two hundred feet long, fifty wide and from fifteen to twenty feet deep, which become filled with snow and ice, and drifting full in the winter remain a small lake until late in the summer time.

(e) Irrigation. In the southern part of Alberta there are wide stretches of excellent land which have an insufficient water supply. The system of irrigation consists of the diversion of a supply of the water from certain streams such as the Bow and St. Mary's Rivers. The channels extend fifty and a hundred miles and the water on being distributed makes the desert to blossom as the rose.

CHAPTER XII.

THE SOIL.

Over the drift formation of our three provinces lies as a rule, the soil. It is the boast that there is no country in the world, approaching it in extent, which has so fertile a soil. That very often this layer is four or more feet in thickness raises the question, How was it produced ? The late Professor Shaler, of Harvard University, has given a most minute and clear description of the process, which we to some extent follow. When the clay marl which the glacial lakes deposited, was raised above water as the lakes disappeared, the formation of soil at once began. The sun produced evaporation, the rain fell in heavy drops, loosening particles of the drift, and concretions of fine debris were formed. Gradually low forms of plant life, such as lichens and mosses, attached themselves to this dust, and when moist, grew. By degrees a mat of this herbage covered the land surface, drying up in the dry season and growing when it became moist. On the decay of the older lichens, carbonic acid was formed and absorbed by the water of the mass. Water charged with carbonic acid becomes fifty times as powerful to dissolve any substance as compared with pure water. By degrees plants of a higher class took root. They ripened and died and then vegetable substance was added to the soil. In a hundred years sufficient soil was formed to be a thin coat of soil. In a century more the blowing on of dust from the drying substance of the land and from distant hillsides resulted in a soil sufficient to support herbaceous plants and even small trees. What we may call a "humus" was formed and the region brought into the realm of living beings. The open plains would receive much greater additions of material than a woody or rocky region does.

In addition to such slow formation soil is formed in the lowlands and on the banks of rivers, this being called "alluvium." Much of the real alluvial soil along the Red, Assiniboine and Saskatchewan Rivers was formed in this way. We have thus an area of detrital plains. The alluvial beds are at first seen but little above the water but successive floods add more and more to them. On the rise of the land by movements of the earth's crust, "terrace" lands are formed. It thus came about that almost all the first seats of agriculture were on the banks of rivers. Thus it was that through the added soil "Egypt became the gift of the Nile." It is stated, that in some forest countries two feet in depth are found made up of entirely decayed vegetable matter.

Even more easily do the long grasses and herbage of the prairie —the masses of dense plants of the Sunflower family and of the Pea family—decaying add their substance to the ever deepening soil. Two living agencies are employed in working into a solid mass all the new elements. Darwin has spoken of worms as being such an agency, and undoubtedly the industrious ant accomplishes much in sandy soils. So gophers, mice, badgers and other animals do their part in this growing process. When the soil comes under the influence of man in agriculture, new features are assumed by it. The water penetrating it carries downward particles of the upper soil. The freezing of the sub-soil and its thawing again leads to the upper soil being made more porous, as the solid matter is pushed upward. The water also absorbing as before, the increased amount of carbonic acid from the decaying vegetation, dissolves out particles in the upper soil taking them to the sub-soil. When in the work of the farmer the ploughshare disturbs the soil, it is chiefly the upper portion which is affected and the sub-soil becomes harder. The dust of disintegrating rocks is carried by the wind, and being made up of potash, soda, phosphates and the like, adds these elements to the "humus."

One of the most remarkable features of the soil has been made known in late years by microscopic study. This is that the vegetable elements of soil are worked into shape for the roots of the young plant by the agency of ferments in the soil. These so-called ferments are more properly exceedingly minute vegetable organisms known as bacteria.

One of the problems met with in the arid regions of the United States is the presence of alkalies in the soil. Except in the irrigated district in the southern part of Alberta, the question of alkali has not become a serious one in Western Canada. There are, it is true, here and there spots of alkaline land but they are exceptional. Our Canadian soils have usually a large quantity of lime in them from the grinding down of the Palæzoic rocks, and lime is regarded as a corrective of the alkali. The presence of alkali in the soil is, however, chiefly made known by its affecting water. Unless there is an excess of magnesian sulphate (Epsom salts) in the water, there seems little that is hurtful in the use of a water slightly alkaline in taste. The varieties of water in Western Canada is one of the most remarkable things which the traveller meets. In the hotels of the important places such as Winnipeg, Portage la Prairie, Brandon, Regina, Calgary and Edmonton, the traveller obtains cool, sparkling water, which though sometimes hard, yet has no taste of "smokiness" or alkalinity, and is most agreeable to the taste. Persons in some localities who have become accustomed to a slightly alkaline water do not object to it. It would seem as if in course of time

the soil about a well would leach out the alkalies which the rains do in all moist countries. A well from which a limited supply of water is drawn is likely to be more affected than one much used.

The fertility of Western Canada may be traced to the large amount of mineral ingredients in the soil which are demanded in the growth of cereals. The presence of phosphoric acid for the grain of the cereal, of silicic acid for the stalk of the wheat and of nitrogen in the humus for the heavy rich kernel of Western Canada wheat, as well as soluble potash and soda, is very remarkable, and explains the enormously productive character of the soil. We have the details of the composition of the average soil of Minnesota and North Dakota and they are much the same as those of Western Canada. The following comparison with Ohio, one of the best states of the American union, speaks for itself.

	Lime	Potash	Soda	Phosphoric acid	Soluble Silica	Nitrogen in Mumus
Minnesota and North Dakota Western Canada	.70	.33	.36	.21	8.46	6.67
Ohio............	.28	.26	.35	.11	—	—

APPENDIX.

FORESTS AND THE SOIL.

In our account of the origin of the soil it was seen that the very beginning of soil-formation is in the plant. The lichen and the moss bind together the debris and dust, then the ferns and castaway sea weeds come in. By and by the herbaceous plants can get a footing in the thin soil layer. Last the trees spring up and do their share in holding, enriching, aerating, and in other ways improving and protecting the soil. The destiny of the trees and the soil are thus closely bound up together. No. I Map shows that a part of Western Canada is wooded but much is prairie. It is equally important to save the trees in the wooded districts and to earnestly engage in tree-planting on the prairies. The following pages on this important subject were written by the author under the auspices of the "Canadian Forestry Association."

See what a tree is and does. A tree is a great and beautiful organism placed in Nature with a purpose. By its root it is anchored to the ground and made secure in its standing place. Here it may grow and feed ; much of its food, it is true, is from the air, but here also it receives nourishment from the roots. As Grant Allen has said, "The root drinks water. The hairs and tips of the root absorb moisture from the soil, and this water circulates freely as sap through the entire plant." Just as in the human body the blood in its course passes to the lungs to be purified and made fit for use, so in the tree the sap is carried through its channels to the leaves ; and these allowing it to come into contact with the air serve as lungs to make it ready for the refreshment and building up of the tree.

The way in which this is done is very wonderful. The tip of the root is the part of the plant which exercises the greatest discrimination and ingenuity, so much so, that Darwin likened it to the brain of animals. For it goes feeling its way underground touching here, recoiling there, insinuating little fingers among pebbles and crannies, and trying its best by endless offshoots to fix the plant with perfect security.

These little fibres or roots are very soft and will take in the water from the earth, but we must wait to see how the tree does it. The tree begins its work far up at the leaves. The outer layer of the green leaf, as we find under the microscope, is made up of clear, flat cells, full of water, and the green stuff lies below this. See then what happens. The sun heats up the leaf and a little moisture goes off as steaming vapor, and this leaves an

empty space. Now, just as you see the water rise in a pump, when the handle is worked to make a vacuum, so the particles of water rush in to fill that vacancy, and so on up the twig, and from the branches, then from the trunk, and even from the root comes up the watery sap. This extends nearly to the end of the root which is open and porous so that when the last cells are vacant the water presses in from the soil on the outside, and so up and up the sap goes, just as if it had the power itself to climb.

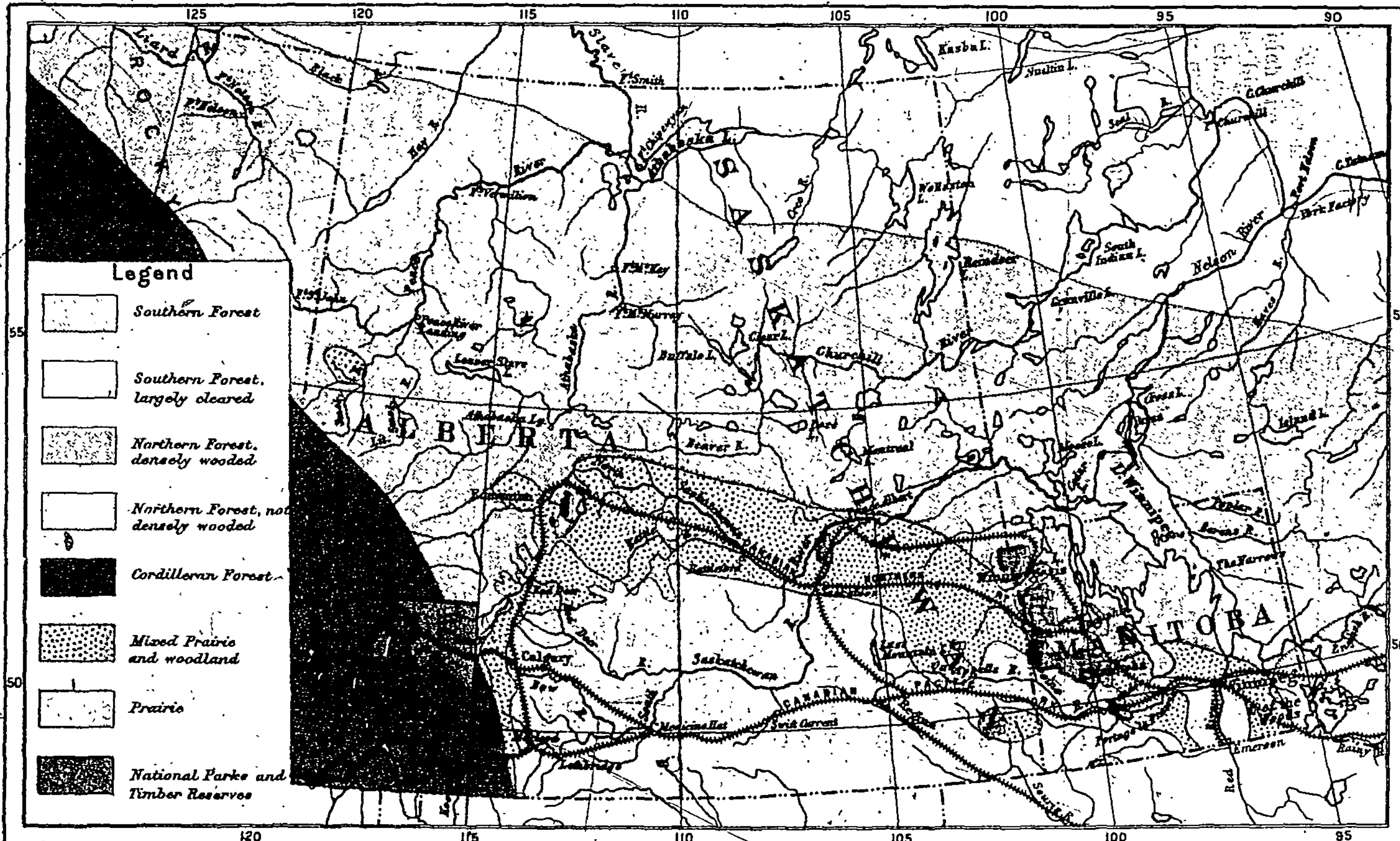
In this way the sap, made up of water, containing salts and other substances from the earth, may be said to rise, leaving its contents on the way to build up the tree, and then it in part as finest vapor, escapes from the leaf pores and finds its way into the air. The leaves are thus the mouths of the plant, for in Spring, when the leaves are not full-grown, the sap cannot rise, but gorges the stem so that when we pierce it it bleeds; so in the summer when the leaves are broad and green and fresh, the sap circulates more freely and the evaporation from the leaves of the tree is greatest.

But this is not all. When we examine the leaves carefully with a microscope of some power it is found that besides the small pores spoken of there is a special arrangement of a very wonderful kind, of a large number of rounded openings called "stomata," or mouths. By these much more moisture is allowed to escape. In the white lily there are from 20,000 to 60,000 stomata in a single square inch on the lower side of the leaf, and perhaps 3,000 on the upper surface. These mouths are really self-acting valves. They consist of two narrow cells lying alongside each other. When these are moistened they expand, become moon-like and leave an opening between them. By this the moisture escapes. When the cells dry, they straighten and close, allowing no escape of vapor. Thus when there is too much sap in the leaf they open and allow an escape of water as vapor; when too little they close and retain it.

The thick-leaved cactus, which is found in a few places in Manitoba, also largely in some localities farther west, and is fitted for dry regions, has stomata, but they do not act at all in the dry season of the year. Water plants have no stomata.

Thus we see that the greater the heat and the brighter the sun, if the plant is well provided with moisture, the greater is the evaporation. It is marvellous in our temperate zone, to find the enormous escape of moisture in our plants and trees. A sunflower, three and a half feet high, which has with its wide leaves as much surface as a platform 25 yards square, gives off a pound and a half of water in 12 hours; and a seedling apple tree with a surface of leaf as large as a centre table, three feet four inches square, evaporates nine or ten ounces a day, or about the amount that a man would perspire in that time.

FOREST MAP OF WESTERN CANADA



Reprinted from map compiled by James White, F.R.G.S.
Geographer, Department of the Interior

We see then, that the tree is really a pumping apparatus by which the supply of water coming from the earth passes up into the higher air. The tree brings up the water as it is needed; it checks the waste of water by which, if there were no trees, the moisture would all be carried from the treeless plain by the heated air and transported in clouds to the distant sea; it is indeed a mysterious workshop which builds up a thing of beauty and also supplies the air with a requisite and timely supply of moisture.

If one tree is so useful what may be said of a plantation or a forest! It cannot but be a powerful regulator of climate. When the warm winds would in a day or two, as we see in the case of our Chinook winds in the far West, lick up every trace of moisture from the prairie, this is prevented by the occurrence on a landscape of shrubs, and bushes, windbreaks, avenues, clumps of trees, bluffs and timber reserves. These preserve the moisture to be used by the growing herbage in the warm weather of summer and prevent the droughts to which all prairie countries are at times subject.

The loss of our forests is a calamity. To-day Ontario is lamenting its loss; it is trying to reforest its bare hills from which the streams now largely dried up took their rise; IT IS PAYING THE PENALTY FOR DEEDS OF DESTRUCTION, WHICH ALWAYS COMES. What would Manitoba not give to-day for some of the forests, which went up in smoke at the "logging bees" of our mother province!"

And is Manitoba blameless? Beautiful groves of splendid oak trees in Southern Manitoba, and on the Pembina Mountains have been cut and slashed in the most reckless manner by the settlers. Whole belts of timber, along Red River, on Bird's Hill, along the railway line at Tyndall, Beausejour, and Whitemouth have been blotted out. Groves of fair poplar and good oak south of Portage la Prairie are things of the past. The remote Moose Mountain is being denuded of its woods.

No doubt, already, also, in Saskatchewan and Alberta the hand of the ruthless forest destroyer has been felt.

That delightful writer, Washington Irving, says: "There is something nobly simple and pure in a taste for the cultivation of forest trees. He who plants an oak looks forward to future ages, and plants for posterity. Nothing can be less selfish than this."

Perhaps few of us realize how exceedingly important the presence of trees is to us. Like many other good things, we value them most when they have gone. Some of their uses may be pointed out:

(1) *The trees protect from fierce and damaging winds.*—The prairie has its own peculiarities of windage. Its wide and uninterrupted expanse almost always has a breeze stirring. The

movement of the long grass on the prairie before the wind in summer reminds us of the continued motion of the sea. The sultriest day with us in summer has its zephyr, almost always cool and refreshing. Taken altogether, however, the complaint of visitors and new settlers about our prairie is that it is never quiet. "It is always blowing," you will hear men say.

Commencing with the spring, at the time when the farmer is all alert to get his wide fields sown with wheat and other grains, he usually sows the seed on very dry soil, before the coming of the rains which fall late in April or in May. Now in 1897 and 1900, and in other years, high winds rose that destroyed a great extent of the sown grain. In the year 1900, so strong was the wind that along the edges of the fields great drifts of pulverized soil accumulated carrying with them the grains of wheat. In some parts of Manitoba farmers sowed their fields three times in that unfortunate year. Rows of trees and shrubs would almost completely prevent this, and give shelter to the open fields. The same applies to the grain in the state of the green blade, when it is sometimes torn out by the roots by strong winds. At a still later stage the effect of wind upon the ripening grain is seen in the beaten down and lodged tangles into which the fragile stalks are thrown. Avenues, wind breaks and hedges will protect the fields.

In the Canadian West there are certain well-known farm plants of the eastern provinces, which cannot now be freely grown. Red Clover is one of these—one of the most useful fodder plants, as well as being valuable for bee-culture. One may see the clover growing in small strips on the south side of some sheltering bluff of poplar trees in Manitoba. This is a proof that all that the clover needs to be more common and serviceable is a line or cluster of trees to protect it.

This is true of many other plants. Professor Bessey of Nebraska University, the well-known botanist, once stated in recommending that the Government should plant blocks of trees here and there over the prairie areas, that it was his belief if this were done and the prairies should become wooded, that almost all the plants of the eastern states and provinces would find their way to the West and flourish in the shelter from the north wind thus afforded.

All travellers in Western Canada are aware of the great difference there is in cold and stormy weather between an exposed prairie road and one sheltered and comfortable through the belts of forest. The children on their way to school always seek the shelter of the "winter road," if there be such, and tree planting may enable us to protect our most exposed prairie roads.

The Western rancher in winter spends his time largely among his cattle. While conducive to health, the weather is at times

severe for the herds. In former days cattle, following horses who broke the icy crust of snow for them, found good winter pasturage from the dried grass of the prairie. Cattle are still fond of passing a part of the coldest day in the open air. With wind-breaks and belts of trees this may be done with great profit. The cold winds are warded off and the cattle thrive in the fresh air. Thus, for man and beast alike the belt of trees affords a much-needed shelter.

(2) *The trees are reservoirs of moisture.*—To the south of Saskatchewan and Alberta, south of the United States boundary line, lies a barren region known as the Great American Desert. Here cactus and sage bush revel in the barren wastes. From this arid region hot winds come northward with withering effect. The herds become thirsty and excited, the crops are sometimes withered in a few hours, and human beings are parched and in distress. The ground bakes and cracks.

Stratum after stratum of air falls down to come in touch with the dry earth, soon also to be heated and dried. In this way the prairie becomes like a desert. But if there be belts of trees the shade prevents the earth becoming so hot, the foliage of the trees keeps the moisture from evaporating, and the stomata of the leaves close up and retain the watery sap. Thus the forest checks the dangerous tendency to drought found in many parts of the wide plains of the West and if extended, may prevent such a damaging drought as was seen in Manitoba in the summer of 1900.

(3) *Trees make a humid climate.*—Most of us know the way in which winds upon the earth's surface originate. The great expanse of sea surface at the Equator is acted on by the intense heat of the tropical sun and evaporates copiously. It is said that in the equatorial portion of the earth there is evaporated in a single year not less than sixteen feet of water over the whole surface. This in the shape of vapor is carried aloft; the cooler air from the north rushes in to fill the vacancy and the heated rising air goes north as the upper currents and carries the moisture with it.

Great vapor waves of this kind constitute the clouds with which we are familiar. If the surface over which this passes is dry and hot, the upper winds go on to the far north until they are chilled to rain, or more commonly snow, by the icebergs of the north. But if the surface is covered with trees, the earth is not so greatly heated, the trees preserve a lower temperature of the upper air belt and cause the moisture of the upper air to descend in the form of rain.

The hotter the air, the more moisture will it hold without sending any down as rain. Thus at a falling temperature a portion of air will not hold as much moisture as it did when the

temperature was higher. For example, a cubic foot of air at 80 degrees can hold 11 grains by weight of moisture, but at 66 degrees it can hold only 7 grains. Now, when the hot wind carrying moisture from the south, passes over a wooded country, where the temperature of the forest is lower, the wind is reduced in temperature. Should it fall the fourteen degrees spoken of, 4 grains of moisture in every cubic foot not being able to be retained, will descend as rain. Thus the forest acts as a cooling agent to produce rain.

Again, in forming dew, the trees of the forest play an important part. Dew, as is well known, is produced by the grassy surface of the earth giving off its heat and becoming in the evening cooler than the air above it. The constant evaporation from the forest also makes it cooler, while the shade preserves a lower temperature. Now when a cubic foot of air has say 90 degrees of temperature, and it is cooled down to 75 degrees, as the dewpoint, dew will be deposited upon the cooling surface of the grass and leaves. Should the night be cloudy, the heat is not given off from the earth, but is driven back by the clouds and there will be no dew. When the sky is clear the heat is carried away, the forest and other surfaces cool down and the dew is formed. It is thus plain that trees are very important agents in preserving to a country a humid climate.

(4) *Trees preserve the springs and rivers.*—All people have accounted springs of water as precious. The camel and his Arab driver on the desert both pant for the palm trees in the distance that indicate a green oasis in the desert, which proves the existence of springs of water. These springs are simply the accumulation of the waters brought by rainfall in some bed of porous earth that will allow it to gather there. Where the trees are, are the springs, and where the springs are the trees can grow. The trees have their main roots, and especially their fibrous delicate rootlets, immersed in the springs. When the springs become filled and the earth of the highland cannot contain the water, some of it runs off and forms, first, the rivulet or brook, then the brooks gather into the river and the brimming river flows through the lower land to refresh it. How greatly we appreciate pure water for man and beast!

It is now plain that to have a river, the fountain or source must be protected.

Western Manitoba and Eastern Saskatchewan are largely dependent on the water system of the Assiniboine River. This river has its rise in the Riding Mountains, a cluster of high hills in the northern part of the province. Several streams run from the springs of this height of land of Riding and Duck Mountains. The main branches—the Shell River, Little Saskatchewan, and the Birdtail, flow from the south side, and from the north side

come the White Mud, Big Grass, Ochre, Dauphin, Vermilion and Valley Rivers. North east of Turtle Mountain there is also, in Southern Manitoba, a network of streams running eastward, watering the country along the chain of lakes—Pelican, Lorne, Louise, Rock, and Swan Lake. Moose Mountain likewise has flowing from it several streams. Now these highlands are well timbered, but are in imminent danger of being deforested, Settlement is naturally threatening these important forest tracts, by making fires more common, and by cutting the wood for farm and milling purposes.

Cut down the trees and the high hills will become dry and barren. The centres of which we have spoken will have great freshets in the spring as the snows are melted from the bare hill-sides, and will be small by midsummer. All its feeders cut off, the Assiniboine River will be so diminished that it will dry up every season at Winnipeg—a thing of most serious moment.

The Governments, farmers, and citizens of Manitoba, Saskatchewan and Alberta should all resist selfish agitations to have these timber regions opened up for settlement, or to allow the wood to be used so lavishly that the fertile districts of the West would tend to become a barren region.

The vast forests shown in our map north of the Saskatchewan, and the forests in the foothills of the Rocky Mountains in Alberta are of great importance in preserving moisture for the crops and in keeping up the water supply of the rivers.

(5) *Trees regulate the flow of waters.*—The prevalence of floods in some parts of America is a very serious matter. When the rivers are sealed up in winter to a great depth, and the spring sets in so quickly as it does in Western Canada, it ought to be a subject for careful discussion and wise action. The more will this be important since the prairie rivers have as a rule low banks and may easily overflow.

A study of different seasons will show very clearly what the causes of danger are. We have seen some spring times that were slow and backward. The first days of sunshine and mildness were followed by northwest winds and the melting of the snows was checked. Then would come a few days of milder weather and a thaw would set in, soon to be followed by another cold snap. In this gradual way the snows disappeared, the ice melted and there was no fear of high water.

In other seasons the spring was later perhaps and then came on with continuous warm weather, the season passing as is said from winter suddenly into summer. Before the ice could yield to the sun's rays, the melted snows rushed in from the bare, open prairies. The water rose above the ice, and its temperature was such as to interrupt the melting for a time. Such a season has features of danger in it.

One of the greatest losses produced by such floods or high water is the valuable rich soil that is washed away and carried down to the river mouth to lie useless. The preservation of salts in the soil is essential to its fertility.

Imagine what it would be if all the sources of the rivers in Riding and Duck Mountains, in Turtle Mountain, and Moose Mountain, and the forests of the Rocky Mountain foothills were cleared of forest. As it is now, the snow and ice of the sources of these rivers are kept late in melting; the springs are frozen till well on in May and June. This prevents a vast body of water from seeking a channel by the rivers, which are at this season gorged with the inflow from the prairies. In the case of these sources being denuded of their forest protection the melting snow and ice would pass away in a few weeks in April or May and would be a constant source of danger to the country.

But not only the prevention of floods, but also the steady supply of water for the growing crops is of greatest importance. If the influence of forests can be felt on the rivers and creeks till well on in July there is thus produced a practical irrigating agency. The evaporation from the streams and ground moistened by them will bring rain and be of immense value to the country. Such are some of the general advantages of trees. They are a means of communication, a harmonizing medium between the forces of the air and the forces of the soil. "He who plants a tree plants a joy—plants peace."

But in a country where as in Western Canada, elm, oak, maple, and other such trees grow to advantage in sheltered spots, on ridges and elevations, and on the banks of rivers, it is safe to assert that they may be grown till the prairie is well covered by them, and that this will be of immense value to the farmer.

(6) *The presence of trees tends to prevent Summer frosts.*—It is a principle, pretty generally admitted, that the best specimens of cereals—such as wheat, oats and barley—are obtained from near the northern limit of production. Wheat of a good sample, other things being equal, will produce a yield better in quantity and quality in these Western Provinces than can be obtained in Kentucky. Barley of the highest quality grows luxuriantly on the Peace River.

Now, while this is true, yet it is plain to be seen that just as an unexpected and sudden frost may kill the orange blossoms in Florida or California, so there is some danger of summer frosts doing damage, especially to the wheat when it is in August in the flowering or milk stage in Manitoba or the other provinces.

Frost, as even a child knows, arises from the heat being given off from the earth into the air. The earth's surface then cooling down, chills the moisture in the air into dew, and the heat being still given off the temperature falls to 32 degrees Fahrenheit, or

below. At this stage the drop of dew is changed to ice, and should it be lying at the foot of a grain of wheat in the milky stage, freezes the pulpy kernel. When the sun rises and thaws this out, the decay of the grain sets in, and both odor and appearance show the kernel to be injured, and if badly frozen, destroyed.

True, we are free from frosts for many years at a time, but when it does come it is caused by the heat leaving the ground and being carried off to higher strata of air by radiation or to distant localities by wind. As a rule such conditions happen only once or twice in August, and in many years do not come at all. How does the existence of trees affect this?

(a) Forests and plantations will check the wind that precedes the damaging frost and prevent the loss of heat in this way. Except in very high or exposed places, the amount of frost is very small, only a few degrees—at a given point. So that the prevention of such winds would in five cases out of six result in there being no frost. The shelter from the northwest in such places as the southeast slope of Pembina Mountains and the south side of Moose Mountain, has resulted in generally preserving those districts from frost.

(b) The other loss of heat results from the clearing of the sky after rain and the soil losing its heat by radiation into the upper air. Here, too, trees have a beneficial effect. The tree, as we have seen, shades the ground and prevents the heat leaving it suddenly and going upward. The shade of a dense forest, indeed, acts in the same way as a sky full of clouds which prevents radiation of heat and saves from frost. That this is the right theory of the matter may be seen from the fact that large bodies of water such as Lake Manitoba, retain the heat longer than the cooling land at night. The Portage la Prairie plains have thus been saved from frost on several occasions.

And not only will the growth of forests tend to keep a more average temperature in summer, but will make a more equable winter climate. The absence of high winds when trees are grown in sufficient numbers as shelter, and the prevention of the radiation of the earth's heat, especially by evergreen trees, is so considerable, that along with the increasing area of land being cultivated, and the consequent retention of heat in the soil, there is ground for believing that the wide prevalence of blocks of trees in the Canadian West will moderate the winter climate.

(7) *Trees hinder hail formation.*—One of the most destructive agencies in the growing time of summer in all countries is the hailstorm. There is much question as to its origin, but there is no doubt about its harmful and destructive nature. One theory which seems to be gaining ground, though it is hard to see that it meets the case, is that electricity, which is always manifested in severe lightning discharges, has to do with its formation. Cer-

tainly electric discharges accompany the hailstorm, but which is cause and which effect remains to be seen.

A more common explanation of hail is that it arises from upward currents of air which form a sort of whirlwind. It is said that in the front of the hail cloud there is a violent, whirling motion, and that the hail cloud being of two different temperatures, the hailstones form by being alternately hurled from one to the other. During each summer, hailstorms occur on the prairies, and certainly some districts are more subject to them than others. A district of country parallel to one of the high ridges or so-called mountains, is said to suffer from hail. So serious are the hailstorms that Insurance Societies have been formed to recompense for the losses caused by them.

From our standpoint, however, it makes little matter, which theory, whether of electricity or whirlwind, be taken. It is well known that treeless districts are far more subject to hailstorms than others. The trees act as a conductor and cause a steady flow of moisture upward, tending to make it of even temperature. The forest in this view will reduce hailstorms. If the more probable theory of hot and cold currents, and their producing whirlwinds, be taken, it is evident that the block of trees will prevent this. So far as observed, the whirlwinds on the prairies often follow river valleys, or are parallel to chains of hills. Both of these are more or less covered with trees.

(8) *Trees give shade and protection.*—In the sultry days of summer cattle and horses suffer greatly from the fierce glare of the sun, and fall off in flesh. Every farmer should have a few trees left in each field to protect his flocks and herds from the sun. The air of comfort with which the patient cattle, after feeding for a time, find their way to the protection of the spreading elm or maple is a proof of the value of the shelter. The "merciful man is merciful to his beast."

The combination of drought with shiftless farming, idleness and ignorance, coming upon a country leads in the end to famines. An expert writer on famines has given it as his opinion that when the trees are not denuded from a country, but are preserved, they afford protection in general to the agriculture and to the people, and remove one of the dangerous elements in nature which produce famines. Another good writer has said, "There can be no doubt that one of the causes of the terrible famines in India and China is the unwise denudation of mountain slopes, where the forests formerly absorbed a large portion of the rainfall which now quickly runs off to the sea."